PIERCE COUNTY

COUNTYWIDE WATER QUALITY MONITORING PLAN

DRAFT

REV 1

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PREPARED FOR

PIERCE COUNTY WATER PROGRAMS

PREPARED BY

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SEATTLE, WA

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1. INTRODUCTION

Pierce County retained Brown and Caldwell (BC) to prepare this Countywide Water Quality Monitoring Plan (CWQMP) for the Pierce County Stormwater Management Program. This CWQMP provides a monitoring program that meets the general intent of the Municipal Separate Storm Sewer NPDES Permit (also known as the "Phase I MS4 permit"). The first draft of this permit (May 2005) stated two questions for the monitoring program to address in determining the effectiveness of the stormwater management program in protecting and restoring water quality and beneficial uses:

> Is implementation of the Stormwater Management Program preventing impacts from the effects of new development by controlling construction and post-construction runoff?
>
> Are the Permittees preventing impacts and seeing improvements to beneficial uses by implementing a comprehensive stormwater management program?

This CWQMP has been designed to help answer the questions listed above, and provide information that will enable Pierce County to improve its stormwater management program. The County's primary motivation for monitoring is to guide the types and locations of management strategies needed for protection and enhancement of receiving water quality and beneficial uses in Pierce County. In fact, the County began development of this CWQMP before the draft MS4 permit was issued.

The second draft of the MS4 permit, released in February 2006, specifies general stormwater discharge characterization monitoring. This type of monitoring is unlikely to provide information that will help Pierce County improve its stormwater management program (see Pitt et al. 2004). Therefore, this CWQMP does not prescribe extensive stormwater characterization monitoring.

This CWQMP contains two main monitoring components:

1) Monitoring to assess overall stormwater program effectiveness in protecting and restoring receiving water quality and beneficial uses. This involves three receiving water monitoring elements:

   i) **Long Term Status and Trends (LTT)** monitoring employs bioassessments (benthic macro invertebrates), physical channel characterization, *in-situ* bioassays (subject to a pilot program) and flow monitoring at existing County monitoring sites. These methods will assess water quality and beneficial uses in multiple streams selected to represent three general development classes (full-buildout completed, large development potential, and conditions intermediate between these two).

   ii) **Targeted Development (TD)** monitoring compares upstream and downstream conditions to assess impacts of stormwater discharges on the receiving waters over finite periods before and after specific development activity. This monitoring approach employs physical channel characterization, continuous monitoring for instream turbidity, conductivity and other parameters as needed, and *in-situ* bioassays (subject to a pilot program, described in Section 3.3).

iii) **Special Studies (SS)** monitoring employs site-specific tools as needed to develop cause-effect relationships that lead to focused stormwater management actions or responses as part of the County's adaptive management strategy. This type of monitoring could be triggered by results from the LTT or TD monitoring or other needs indicated by the County, and could include any of the above methods, as well as other measures depending on the specific indications of each case.

2) Monitoring to support development of Detailed Implementation Plans (DIPs) or pollutant trading initiatives to meet Total Maximum Daily Load (TMDL) requirements. Ecology has identified a number of water bodies (or segments thereof) in Pierce County as "polluted" based on past violations of water quality criteria. The federal Clean Water Act requires that Ecology establish TMDLs and DIPs for each "polluted" water body, and include the TMDL requirements in the associated NPDES permits for all dischargers into the affected water bodies. For example, Microbial Source Tracking (MST) may be used to help identify bacteria sources and develop control measures for fecal coliform TMDL DIPs.

The CWQMP was developed based on several documents previously prepared by BC and reviewed by the County. Development of this CWQMP began before the first draft of the revised MS4 permit was released by Ecology in May 2005. The monitoring program goals, objectives, and strategies were taken from the Task 4 *Monitoring Needs Assessment Report* (completed in mid 2005) and updated as needed based on several meetings with County staff. Data management infrastructure recommendations will be covered in other work, based on the Task 5 *Data Management Needs Technical Memorandum*. Please refer to those documents for additional information.

This CWQMP was prepared in accordance with Task 6 of Pierce County Work Order No. D053-000-1. As specified in the Work Order, the format of the CWQMP is consistent with Ecology's guidelines for Quality Assurance Project Plans (QAPPs) and includes the following elements:

- Goals for the monitoring program
- Monitoring objectives and strategies
- Standard operating procedures for monitoring, sampling, laboratory data QA/QC, and data management
- Data evaluation and management procedures

2. PROJECT ORGANIZATION

Key project roles and responsibilities are as follows:

1. **Coordination**. Dan Wrye of Pierce County Water Programs will assist in integrating monitoring results in projects and other County initiatives.

2. **Project Manager.** Ms. Heather Kibbey of Pierce County Water Programs will oversee implementation of this CWQMP. In addition, Ms. Kibbey has primary responsibility for coordination with Ecology and other stakeholders.

3. **Monitoring Manager.** Mr. John Collins of Pierce County Water Programs will be responsible for supervising the County monitoring teams. Mr. Collins will also act as the primary liaison with the contract laboratories.

4. **Field Team Leaders.** Rod Gratzer and Sarah Nygaard will supervise collection of all field data, water quality samples and downloading of automated monitoring data. Mr. Gratzer will have primary responsibility for installation and maintenance of automated monitoring equipment.

5. **Analytical Laboratories.** Water quality samples will be analyzed by AmTest, Inc. (Redmond, WA) and microbiological samples will be analyzed by Spectra (Tacoma, WA). Both of these facilities are state-accredited laboratories. Benthic invertebrate samples collected for this CWQMP will be analyzed by Aquatic Biology Associates (Corvallis, OR). . The QA officers of each laboratory are responsible for monitoring and documenting the quality of all work produced by their respective labs for this project, and for implementing corrective action should the need arise. Toxicity testing support, when needed, will be conducted by the Nautilus Environmental laboratory (Fife, WA). The Institute for Environmental Health (IEH) in Seattle, WA, will perform Microbial Source Tracking (MST) procedures on fecal coliform samples collected for bacteria TMDLs.

2.1 Project Schedule

Pierce County will implement this CWQMP according to the schedule listed below, which may be adjusted based on the availability of resources within Pierce County Water Programs

- *Program Effectiveness Monitoring.* The approximate schedule for each element monitoring approach is summarized below.

    i) **Long Term Status and Trends (LTT)** monitoring in multiple streams representing three development categories will begin in Year 1 of the program and continue annually for at least 5 years. This monitoring involves annual (once per year) monitoring of benthic invertebrates and physical channel conditions, and semi-annual (spring and fall) *in-situ* bioassays (subject to pilot testing). Flow monitoring may also be conducted where gages exist.

ii) **Targeted Development (TD)** monitoring involves monitoring of specific stream conditions above and below discharges from selected new development activities. This monitoring will begin in Year 1 and continue over the duration of the development activity. This monitoring involves continuous monitoring of water quality "indicator" parameters such as turbidity, conductivity; and hydraulic stage; rainfall data acquisition (from existing gages), annual monitoring of physical channel conditions, and semi-annual *in-situ* bioassays (subject to pilot testing).

iii) **Special Studies (SS)** monitoring provides for adaptive management to address data gaps or answer questions identified by the LTT or TD monitoring work or other County needs. For example, this monitoring could involve grab sampling and analysis for total suspended solids or other parameters in order to establish a correlation with turbidity. Therefore, the schedule for special study monitoring will be determined on a case-by-case basis.

- *TMDL Monitoring*. Monitoring related to TMDLs will be conducted on a priority basis. As discussed in the *Monitoring Needs Assessment Report*, priorities for TMDL monitoring will be based on the percentage of each 303(d) listed basin that is under Pierce County's jurisdiction and the constituents of concern. Priorities for monitoring will need to be adjusted over time as the 303(d) list changes or if new TMDLs require monitoring as part of their Detailed Implementation Plans (DIPs). The schedule will depend on the availability of Pierce County resources for monitoring.

3. PROJECT BACKGROUND, GOALS AND OBJECTIVES

3.1 Background

3.1.1 Existing County Monitoring Programs

Pierce County Water Programs has existing biological and chemical/physical monitoring programs. The biological monitoring program is summarized in the 2005 Monitoring Needs Report. These monitoring activities have been performed to address specific water quality problems (e.g. shellfish contamination) and to provide data for basin planning.

A number of other entities perform water quality monitoring within Pierce County, including the Puyallup Tribe of Indians, WA Departments of Ecology and Health, City of Puyallup, and USGS. Most of the monitoring activities have been short-term studies focused on specific needs or issues, such as TMDL development. However, Ecology and the Puyallup and Nisqually Tribes have been engaged in longer-term water quality efforts. Ecology has established two long-term ambient water quality monitoring stations, one on the Puyallup River and the other on the Nisqually River. The Tribes monitor water quality (primarily DO, temperature, pH, and specific conductance) at a number of locations in the Puyallup and Nisqually basins to characterize ambient conditions and fish habitat. In addition to these various studies, faculty and students at Pacific Lutheran and other colleges and universities have conducted water quality monitoring in the County.

Pierce County does not currently conduct water quality monitoring to directly evaluate the effectiveness of specific stormwater best management practices (BMPs). Rather, the County relies on BMP evaluations performed by other entities such as University of Washington (UW), Ecology, WSDOT, and BMP manufacturers. Water Programs contributes $10,000/year to the UW's Center for Water and Watershed Studies for stormwater-related research activities.

3.1.2 TMDLs

Ecology has developed TMDLs for approximately 18 water bodies (or segments thereof) in unincorporated Pierce County (see Section 4). More than one-half of these are for temperature and sediment problems in streams located in commercial forest lands in the eastern portion of the County. TMDLs are enforced through the NPDES permits for point source discharges to the water body. None of the existing TMDLs explicitly require monitoring of Pierce County's MS4 discharges. However, the TMDL report for South Prairie, Ohop, Lynch, and Red Salmon Creeks notes that the TMDL requirements will be incorporated in Pierce County's MS4 permit (Ecology 2005).

Based on past excursions of state water quality standards, Ecology has identified approximately 30 "polluted" freshwater bodies in Pierce County (see Table 4-3). Section 303(d) of the Clean Water Act requires that Ecology develop TMDLs for these "polluted" waters. About two-thirds of these water bodies were listed based on elevated fecal coliform bacteria levels. Nine streams were listed for temperature; however, one (Clearwater Creek) is located in forest lands upstream of Mud Mountain Lake, and three of the listings pertain to sub-basins where unincorporated Pierce County comprises less than 2% of the area. Five streams were listed for dissolved oxygen, and four lakes were listed for phosphorus.

Some of the 303(d) listings were based on sparse or old data. It is possible that additional monitoring could show that some of the listed water bodies actually meet water quality standards, and may therefore be removed from the 303(d) list. On the other hand, additional monitoring could merely confirm that the water bodies are in fact "polluted." Thus, monitoring to support potential de-listing should be limited to water bodies where there is strong evidence that the listing was made in error, or no longer reflects current conditions (e.g., situations where a major source of the listed pollutant has been eliminated).

As noted above, most of the listings in Pierce County are for fecal coliform. Fecal coliform levels tend to be highly variable, and exceedances of fecal coliform standards are fairly common in urban streams. Consequently, it is unlikely that additional monitoring would support de-listing for fecal coliform, unless a major source was eliminated from the system after the previous monitoring had been completed.

Ecology typically develops fecal coliform TMDLs that specify percent reductions in fecal coliform concentrations at certain locations in the receiving water body. The Detailed Implementation Plans (DIPs) for attaining the TMDLs may specify control measures based on little information about the key sources. Fecal coliform source identification monitoring can help ensure that TMDL allocations are appropriate and realistic, and that DIP control measures are properly focused. However, this additional monitoring does not explicitly yield measures of fecal coliform loading.

Temperature was the second most commonly listed parameter in unincorporated Pierce County. Ecology typically develops temperature TMDLs and DIPs based on water temperature measurements and modeling. Additional temperature monitoring by Pierce County may not provide much benefit in terms of more accurate TMDL allocations or more cost-effective DIP control measures.

American, Steilacoom, Ohop, and Hart lakes were listed for phosphorus impairment. Phosphorus source tracing studies have already been completed for American and Steilacoom lakes. Both studies found that groundwater was the primary pathway for phosphorus transport to the lakes, and that direct stormwater discharges from unincorporated Pierce County did not appear to be major sources (Woodward-Clyde 1998; URS and Brown and Caldwell 2004). The Nisqually Tribe studied phosphorus in Ohop Lake, and found that sediment from commercial timberlands in upper Ohop Creek and shoreline septic systems were the main external sources; stormwater was not identified a phosphorus source (Whiley and Walter 1997). Harts Lake has not yet been studied in detail. A number of lakes within the County have not been sampled in recent years. It is possible that future sampling of these lakes may result in additions to the 303(d) list.

3.2 Goals and Objectives

The overall goals of this monitoring program are to (1) provide Pierce County with a comprehensive monitoring program for its stormwater management program, and (2) support and guide Water Programs' efforts to protect receiving water bodies from stormwater impacts. The County's primary motivation for collecting monitoring data is for its use in determining the types and locations of management strategies needed for protection and enhancement of receiving water quality and beneficial uses in Pierce County. The County recognizes that attaining these broad goals will involve a variety of activities in addition to the monitoring described in this CWQMP. Moreover, the

County has limited resources available; thus, the monitoring program needs to be efficient and cost-effective.

The specific objectives for this CWQMP are listed below.

1. Determine whether receiving waters for Pierce County stormwater discharges are stable, declining, or improving in quality by monitoring biological, physical and chemical characteristics over long periods (e.g. 5 years or more).

2. Help determine whether changes in receiving water quality appear to be attributable to Pierce County's stormwater discharges.

3. Help ensure that TMDL requirements affecting Pierce County are reasonable and appropriate and result in a in a "fair share" of responsibility among discharges or if potential pollutant trading is possible.

4. Provide near "real-time" water quality information that Water Programs staff can use for inspection and enforcement purposes.

5. Provide information that will help support Pierce County's stormwater management decisions.

6. Obtain data that are easily integrated into other Pierce County and regional water quality programs.

3.3 Monitoring Approach

This monitoring program is designed to address the objectives listed above in a systematic and cost-effective manner. The monitoring approach builds on the County's existing monitoring activities and is intended to complement other local and regional monitoring programs conducted by others (i.e. Ecology, University studies, WSDOT, etc). If potential problems are identified, special studies or "adaptive management" monitoring will be performed to help determine the magnitude and likely causes. The program will also provide near "real-time" water quality data that the County can use to focus its stormwater maintenance, inspection, or compliance efforts.

3.3.1 Overview of Monitoring Approach

A three-level receiving water monitoring approach will be used to address the objectives listed in Section 3.2 above.

- **Long Term Status and Trends (LTT)** monitoring involves benthic invertebrate sampling, *in-situ* bioassays (subject to pilot program), streamflow gaging, and physical channel assessment at existing County monitoring sites in selected streams. These methods will assess water quality and beneficial uses in multiple streams selected to represent three general development classes (full build-out completed, large development potential, and conditions intermediate between these two). Biological monitoring will be used because it can provide a direct measurement of impairment level for beneficial uses associated with aquatic life (Karr and Chu 1999; NRC 2001; U.S. EPA 2002). Physical channel conditions will be monitored because the data can "efficiently provide both evaluation of overall stream "health" and guidance on the most likely causative factors in urban and urbanizing conditions," (Scholz and Booth 2001). The monitoring locations were selected based on existing County B-IBI sampling stations and their associated drainage area characteristics, including current and anticipated levels of urban development and the proportion of the drainage area that is under Pierce County's jurisdiction. To discern potential changes over time, each location will be monitored at least once per year for a minimum of five years. Existing stream gages will be used to provide data for long term trends analysis of hydrology and to support potential modeling or flood control needs. Given the typical variability of streamflow, flow data will probably need to be collected for extended periods (i.e. more than 5 years) to allow for meaningful hydrologic trend analysis.

- **Targeted Development (TD)** monitoring involves continuous turbidity, conductivity and hydraulic stage monitoring and *in-situ* bioassays (subject to pilot program) upstream and downstream of discharges from targeted development, and assessment of physical channel conditions downstream. Stream reaches deemed likely to be affected by major new development(s) that are located within LTT monitoring sub-basins will be given first priority for TD monitoring. Stream reaches likely to be affected by new development outside the LTT monitoring sub-basins will be given second priority for TD monitoring. This TD monitoring will be conducted throughout the duration of the development activity, and possibly longer if the data suggest that water quality has not stabilized.

- **Special Studies (SS)** monitoring will be conducted in response to needs identified in the above programs, and/or when additional needs and resources become available. SS monitoring may apply the methods used for the LTT and TD monitoring to additional locations, such as :

  - Upstream and downstream of County habitat restoration sites
  - Upstream and downstream of County reaches of multi-jurisdictional streams, to help assess the extent to which water quality problems originate upstream or within the County's jurisdiction
  - Upstream and downstream of built-out areas where the County is considering water quality retrofitting or other capital improvement projects (CIPs)

  SS monitoring could also include:

  - Monitoring additional locations or parameters to identify the most likely stressors, if the LTT or TD monitoring results indicate declining water quality.
  - Site-specific surrogate correlation sampling for total suspended solids (TSS) (and possibly other constituents) to determine if there is a significant correlation with continuous turbidity or conductivity data. If correlations are significant, then the surrogate could be applied to the continuous data to further elaborate on the constituent of interest, thereby minimizing the need for future sampling.

- Toxicity Identification Evaluations (TIEs), if the *in-situ* bioassays indicate significant toxicity
- Source tracking to identify sources of elevated turbidity or potential illicit discharges

The following summarizes the biological, physical, and water quality monitoring components of the programs outlined above.

- Benthic Invertebrate Monitoring. Bioassessments using the current B-IBI monitoring methods will be conducted to assess the biological condition of selected streams that receive Pierce County stormwater discharges. The B-IBI method has been widely used by Pierce County and other Western Washington cities and counties. It has been subject to extensive regional evaluation and has been shown to be an accurate indicator of aquatic habitat quality in the Puget Sound lowlands (Booth et al 2001).

  B-IBI monitoring offers a number of advantages compared to the traditional, chemistry-based approach to receiving water monitoring.

  - B-IBI provides a direct measure of beneficial use impairment. The traditional approach is based on the assumption that chemical criteria are reliable indicators of a water body's capacity to support its designated uses. Numerous researchers have found that this assumption is often invalid. The NRC (2001) noted that impairment of beneficial uses can be caused by a variety of stressors (e.g., physical habitat alterations, flow modification, changes in the food base), that are not necessarily related to chemical contamination. Chemical criteria do not document biological effects of pollution, so they do not directly measure impairment of designated uses.

  - B-IBI is well-suited for temporal trend analysis (Fore 2004). B-IBI scores are based on multiple metrics and reflect the combined effects of a wide range of factors. As such, they exhibit far less temporal variability than concentrations of chemical constituents. Also, there already exists a large body of B-IBI data for the Puget Sound region, which makes trend analysis easier.

  - B-IBI monitoring is much less expensive than traditional water chemistry sampling and analyses. B-IBI collection and analytical costs per sample are relatively low, and samples are collected only once per year. In contrast, numerous samples are often required to adequately characterize receiving water chemistry.

- In-situ Bioassays. I*n-situ* bioassays have the potential to yield low cost, frequent and clear indications of water quality that can be useful for a stormwater management program. Among the various species and life stages potentially available for *in-situ* bioassays, the recently developed *in-situ* salmonid Early Life Stages (ELS) procedure is well suited because it would yield a direct measure of beneficial use attainment for salmonid spawning and rearing. The ELS test would complement the B-IBI testing because ELS addresses a higher trophic level (e.g., rainbow trout) than the B-IBI. The ELS procedure is relatively new, however. Therefore, this CWQMP prescribes a pilot scale program to determine how best to apply this monitoring method in a stormwater context and at a scale appropriate for the LTT and TD monitoring. This pilot scale testing will be developed and implemented using state of the science and Ecology input to best ascertain the utility and applicability of this test.

The ELS method involves observing the development of fertilized embryos in cages placed in stream channels. The testing period can characterize multiple life stages ranging from embryo development through the swim-up fry stage over periods ranging from 7 days up to about 60 days (depending on temperature). These tests have been used successfully in British Columbia, Canada (Bailey et al, 2005). These tests are based on laboratory methods used for ELS testing of other species (USEPA and ASTM methods). The ELS *in-situ* testing would target seasonal spawning periods of local salmonid species of interest in the fall (anadromous, e.g., Chum and Coho salmon) and spring (residents, e.g., rainbow and cutthroat trout).

Bioassays such as ELS are effective indicators of toxicity that can provide more information at much lower cost than analysis of individual chemical parameters. The ELS method is sensitive to certain families of urban pollutants at the various life stages characterized by the test (e.g. PAHs, surfactants in embryo stage; metals in swim-up fry stage), which are difficult to assess by conventional chemical sampling data alone. In addition, the *in-situ* ELS procedure provides several benefits over conventional laboratory bioassays because it:

- tests an organism that is relevant to local streams (given local hatchery availability can be used with a variety of salmonids, such as rainbow and cutthroat trout, and Coho, Chum and Chinook salmon)
- tests an early life stage that is directly comparable with a beneficial use (spawning and rearing)
- tests a longer exposure period that can integrate multiple stormwater discharge periods
- provides multiple, progressive effects measures
- uses readily available and inexpensive test organisms and deployment “hatch boxes” that are reusable
- requires minimal training
- may be amenable to volunteer support
- prevents sampling errors and issues with episodic representativeness, which often hamper traditional chemical constituent sampling
- prevents the need to adjust sample water to laboratory conditions and provide reference toxicants
- presents opportunity and minimal costs to restart an invalid test
- allows minimal site visits (monthly intervals, combined with other field work)

The *in-situ* ELS tests complement the B-IBI testing because it:

- evaluates direct effects on a valued ecological component (i.e., salmonid of interest)
- provides an additional, higher trophic level organism and specific, sensitive life stage relevant to local receiving waters and beneficial uses
- provides finer time-scale resolution where needed because it can be run multiple times/most months of the year
- provides an organism and life stage that is often more sensitive to urban pollutants than invertebrates
- provides a biological metric for sampling locations that cannot be characterized by B-IBI due to inherent limitations of the B-IBI sampling method (i.e. the ELS testing can be done in a low gradient stream without riffle habitat/substrate, or can be conducted in a concrete channel to ascertain existing water quality issues prior to planning a channel restoration effort)

The *in-situ* ELS testing responses will serve as baselines to compare sites over time. In addition, the *in-situ* test enclosures provide an opportunity to assess gross sedimentation impacts. The test enclosures are protected and anchored by onsite or imported gravels, which provide potential test habitat for drifting invertebrates to settle on that might otherwise be transported through the reach of interest. Because the gravels are removed prior to examining the hatch boxes, invertebrates that have settled/colonized this desired substrate can be characterized, providing further insight regarding potential biological conditions in areas where suitable habitat (i.e., substrate) may be limited.

- <u>Physical Channel Monitoring.</u> Physical channel conditions will be monitored to establish current conditions and document changes over time. Channel conditions are relevant to urban stormwater management because urban runoff can alter physical conditions in receiving water bodies and thereby impair their biologic health (Booth et al 2004). According to Horner et al. (1997), "In a majority of settings, the most rapid and severe degradation is a consequence of physical effects, particularly high flows and riparian alteration, not chemical contamination." Channel conditions will be monitored for channel incision and the parameters recommended by Scholz and Booth (2001) for urban streams in the Puget Sound region.

- <u>Continuous Water Quality Monitoring.</u> Water quality probes and data loggers will be used to continuously monitor receiving water turbidity and conductivity. Stormwater and receiving water quality are often highly variable. Consequently, many observations are needed to characterize water quality and enable detection of trends. Continuous monitoring will allow the County to collect thousands of water quality measurements with a high degree of resolution, enabling a much greater understanding of pollutant behavior in the water body (Burton and Pitt 2001). In contrast, obtaining sufficient data using traditional episodic sampling and chemical analyses (such as prescribed in the draft NPDES permit) would be prohibitively expensive (Scholz and Booth 2001).

Turbidity will be monitored because it typically has a strong correlation with total suspended solids (TSS; Ankorn 2003; Uhrich 2002; Eads and Lewis 2002; Packman et al. 1999). TSS is directly relevant to stormwater management, as TSS is often elevated in urban streams due to upland and channel erosion, and many stormwater treatment BMPs function primarily by reducing TSS (Center for Watershed Protection 2003; Ecology 2005). Turbidity can sometimes be correlated to bacteria or other stormwater contaminants. The *Stormwater Effects Handbook* recommends continuous turbidity measurement as an adjunct to biological observations in wet-weather receiving water studies (Burton and Pitt 2001).

Conductivity typically has a strong correlation with total dissolved solids (TDS). Thus, continuous monitoring of conductivity will provide a good indication of TDS concentrations and trends.

Because water quality can be substantially different between the stormflow and baseflow periods of the hydrograph, stage will also be monitored continuously to provide data indicating these two periods. Stage can be readily measured by a pressure transducer that is part of the continuous monitoring equipment. Alternatively, a nearby existing stream gage may lend itself well to interpreting flows for a particular continuous monitoring installation. The stage data will aid in interpretation of the water quality data by indicating relative hydrograph shapes and responses to storm flow.

- Hydrological Monitoring. Continuous streamflow monitoring will be continued at selected Pierce County gaging stations. These gages would most likely be located within the subbasins monitored for the LTT program. The flow data will be analyzed to discern potential long term trends and help determine whether stormwater flow controls are effective in minimizing hydrologic changes due to new development. The streamflow data may also aid model calibration and flood control needs as particular CIPs emerge (e.g. regional facilities, basin plans, large developments, etc). Where available and appropriate, data from USGS gaging stations may also be used in these analyses.

  Streamflow data can be used to compute certain metrics that estimate the potential hydrologic impacts of urbanization. Booth et al. (2004) found that two metrics "succeeded in capturing the hydrologic effects of urbanization, despite local variability in soils, geology, and watershed topography among Puget Sound lowland basins." These metrics are the average annual fraction of a year that the mean daily streamflow exceeds the mean annual flow (T_{Qmean}), and the fraction of the time streamflow exceeds the 0.5 year flood ($T_{0.5yr}$). These metrics should be evaluated about every five years to discern trends and determine their statistical significance. However, given the variability inherent in streamflow in this region, many years of flow data may be needed to support meaningful analysis of potential trends in these hydrologic metrics. Consequently, long term flow monitoring is recommended.

3.3.2 Overview of TMDL Monitoring Approach

Monitoring related to TMDLs will be done on a case-by-case basis. TMDL monitoring priorities are based on the percentage of the drainage area under County jurisdiction and the constituents of concern, as well as the stage in the TMDL process. The monitoring schedule will depend on the availability of County resources. Please refer to the *Monitoring Needs Assessment Report* (BC, 2005) for more information on the current 303(d) list and the monitoring prioritization criteria.

Pierce County's TMDL monitoring program will initially focus on fecal coliform because about two-thirds of the unincorporated Pierce County water bodies on the current 303(d) list are listed due to fecal coliform. Also, fecal coliform TMDLs and DIPs are often based on limited information on the actual sources or causes of the fecal coliform exceedances, and may therefore specify inappropriate load reductions and/or misdirected and unduly expensive control measures. Identification of key sources can help ensure that fecal coliform TMDL allocations and DIP control measures are reasonable and appropriate. Therefore, the first priority for monitoring will be for water bodies with recently approved TMDLs, but where DIPs are yet to be developed (e.g., Red Salmon Creek, Ohop Creek). Water bodies scheduled for TMDL development during the next two years will be assigned second priority.

In some cases, it may be possible to identify the key bacteria sources based on land use and conventional water quality data. Simple inspections may yield cost effective information, where bacteria sources and their linkages to a particular stream's bacteria levels are readily apparent, such as a dairy located directly adjacent to the water body. However, where the water body may be affected by multiple sources, this CWQMP recommends Microbial Source Tracking (MST) using DNA ribotyping to identify sources of fecal coliform in the receiving waters. The recommended MST method has been widely used in the U.S. and Canada, and has been shown to provide accurate identification of sources in "blind" studies. For the Clarks Creek Pollutant Reduction Study, the City of Puyallup used MST to identify sources for more than 90% of the bacteria samples analyzed. The general MST approach, which is described in Appendix F, must be tailored to local conditions (e.g., land use, drainage network, availability of existing water quality data, key data gaps, etc.) in each listed water body.

3.4 Relationship of Program Elements to Monitoring Objectives

The following describes how the monitoring program will meet Piece County's monitoring goals and objectives.

Objective 1: Determine whether receiving waters for selected Pierce County stormwater discharges are stable, declining, or improving in quality.

The monitoring program will address this objective by providing information on biological (B-IBI and bioassays), physical (channel conditions), and water quality (continuous turbidity and conductivity) conditions at key locations over time. The B-IBI and bioassay data will provide a direct measure of potential beneficial use impairment. The monitoring will encompass sub-basins and reaches that are expected to undergo substantial new development, and thus have significant potential for water quality degradation due to urbanization. The monitoring will also encompass areas with medium to high levels of existing urban development.

Objective 2. Help determine whether changes in receiving water quality appear to be attributable to Pierce County's stormwater discharges.

If the monitoring data suggest that receiving water conditions at given location are declining, additional evaluations will be conducted to help identify the most likely causes. The biological, physical, and water chemistry data collected for this monitoring program will be evaluated following the approach described in EPA's *Stressor Identification Guidance Manual* (EPA 2001). The B-IBI data will be evaluated in detail to gain insights as to the potential causes for observed declines (e.g., taxa that are particularly susceptible to toxics). The ELS *in-situ* bioassay pilot project data will indicate whether fish toxicity appears to be a concern. Comparison of baseline and current channel conditions will help determine whether physical impacts are important. Continuous water quality (turbidity and conductivity) data will be evaluated to help determine whether suspended or dissolved solids have increased. If the existing data are insufficient to identify the most likely stressor(s), additional special studies monitoring may be initiated.

Objective 3. Help ensure that TMDL requirements affecting Pierce County are reasonable and appropriate and result in a "fair share" of responsibility among discharges.

The County's TMDL monitoring efforts will focus on fecal coliform, because about two-thirds of the 303(d) listed water bodies are listed due to fecal coliform. The monitoring approach may involve Microbial Source Tracking (MST) to identify the specific sources (e.g., human, cow, dog, bird) of bacteria. In some cases, simple inspections may also yield cost effective information about the existence of obvious sources and their linkages to a particular stream's bacteria levels. Each particular case will be evaluated to determine whether simple inspections will suffice, or whether MST methods will be needed to identify key bacteria sources and develop effective control measures. In either case, the monitoring results will be used to help ensure that (1) the County is not made responsible for uncontrollable sources (e.g., wildlife), and (2) that the DIP prescribes practical measures that focus on the key, manageable sources.

Objective 4. Provide near "real-time" water quality information that Water Programs staff can use for inspection and enforcement purposes.

The **Targeted Development** monitoring will involve continuous monitoring of turbidity and conductivity in receiving waters upstream and downstream of rapidly developing areas. These data will allow Water Programs staff to quickly identify potential problems, such as construction site erosion or channel disturbance, and focus maintenance, inspection, and enforcement activities accordingly. These installations can be expanded to provide continuous data for certain other parameters such as temperature, pH and dissolved oxygen. In addition, telemetry can be added to these installations to enable wireless, real-time data acquisition and control that can be used to trigger inspections.

Objective 5. Provide information that will help support Pierce County's stormwater management decisions.

Much of the county's stormwater management program is intended to prevent or minimize the adverse impacts of development. The monitoring program will provide information on receiving water quality and hydrology in sub-basins and reaches likely to experience substantial urban development. If water quality declines or adverse channel or hydrologic trends are observed, focused evaluations and monitoring will be conducted to help determine the likely cause(s). The monitoring results will help the County determine the most appropriate management program to protect receiving waters from the potential adverse impacts of stormwater runoff, and focus its management and monitoring efforts accordingly.

Objective 6. Obtain data that are easily integrated into other Pierce County and regional water quality programs.

The biological, physical, hydrologic and chemical water quality data collected during this monitoring program will be stored in an environmental data management system (EDMS). Pierce County Water Programs plans to begin developing the EDMS in 2006. The EDMS will be designed to support field planning, sample and data collection, data acquisition (including data loading, hand entry of data, and data verification), data validation, and analysis and reporting. Thus, the EDMS will facilitate the dissemination of the monitoring results to other Pierce County and regional water quality programs and to the public.

4. STUDY AREA DESCRIPTION

Pierce County covers approximately 1,800 square miles in western Washington State (Figure 4-1). The County encompasses over 20 incorporated areas (i.e., cities and towns), unincorporated areas, and state and federal lands (e.g. two military bases, Mt Rainier National Park, commercial timber land). Pierce County has jurisdiction over unincorporated areas but no jurisdiction over incorporated cities and towns or federal lands. The County has limited jurisdiction over privately owned commercial timber lands, as these are regulated primarily by the state Department of Natural Resources.

The unincorporated portion of Pierce County covers approximately 900 square miles and includes portions of four Water Resource Inventory Areas (WRIAs). Unincorporated Pierce County encompasses roughly 3,300 miles of streams and rivers, as well as a number of lakes. Table 4-1 lists the major watersheds in the County.

Table 4-1. Pierce County Drainage Basins

Watershed Name	Total Area	Pierce County Jurisdiction Area		Total Water Course Length	Pierce County Jurisdiction Water Course Length	
	(Mi^2)	(Mi^2)	(%)	(Mi)	(Mi)	(%)
WRIA 10						
SOUTH PRAIRIE CREEK	90	76	85%	378	294	78%
BROWNS DASH POINT	13	1	8%	22	1.6	7%
CLEAR/CLARKS CREEK[1]	33	27	83%	43	31	73%
MUD MOUNTAIN	59	12	19%	123	24	19%
UPPER CARBON RIVER	97	36	37%	446	157	35%
LOWER CARBON RIVER	40	38	95%	153	145	94%
UPPER WHITE RIVER	400	69	17%	2,105	374	18%
UPPER PUYALLUP RIVER	169	109	64%	1,004	677	67%
MID PUYALLUP RIVER	58	41	71%	92	69	75%
LOWER WHITE RIVER	36	12	34%	63	15	24%
HYLEBOS	29	2	6%	45	4.2	9%
TACOMA	20	0	0%	10.3	0.0	0%
WRIA 10 Total	**1,045**	**424**	**41%**	**4,484**	**1,792**	
WRIA 11						
LOWER NISQUALLY RIVER	92	1	1%	95	2.8	3%
MASHEL RIVER	84	83	99%	583	581	100%
MID NISQUALLY RIVER	178	80	45%	411	169	41%
MUCK CREEK	90	67	74%	137	108	79%
OHOP CREEK	40	39	98%	221	219	99%
UPPER NISQUALLY RIVER	293	38	13%	1,757	193	11%
WRIA 11 Total	**778**	**309**	**40%**	**3,203**	**1,272**	
WRIA 12						
AMERICAN LAKE	37	1	2%	36	0.0	0%
CHAMBERS BAY	27	2	6%	14	0.4	3%
CLOVER CREEK/STEILACOOM	71	50	70%	51	39	76%
TACOMA WEST	13	0	0%	9.4	0.0	0%
WRIA 12 Total	**149**	**53**	**36%**	**110**	**39**	

Watershed Name	Total Area	Pierce County Jurisdiction Area		Total Water Course Length	Pierce County Jurisdiction Water Course Length	
	(Mi^2)	(Mi^2)	(%)	(Mi)	(Mi)	(%)
WRIA 15						
BURLEY/MINTER CREEK[1]	32	8	26%	63	16	26%
FOX ISLAND	5	5	99%	6.4	6.4	99%
GIG HARBOR[1]	76	37	49%	165	79	48%
ISLANDS[1]	15	9	55%	26	14	53%
KEY PENINSULA[1]	81	52	64%	190	103	54%
WRIA 15 Total	**209**	**111**	**53%**	450	218	
Grand Total	**2,182**	**897**	**41%**	**8,248**	**3,322**	

[1]These are grouped for convenience because they are relatively small, contiguous watersheds with multiple creeks in each.

Figures 4-2 through 4-5 show the existing and potential urban land uses in each of the four WRIAs in unincorporated Pierce County (though portions of WRIA 26 (Cowlitz River) are in Pierce County, there are no unincorporated areas in this WRIA subject to this monitoring plan and there are no TMDLs or 303(d) listings for this WRIA). These figures show that most of the current and potential urban development[1] lies primarily in the western portion of the County. Areas expected to undergo significant new urban development include the Key Peninsula and Gig Harbor areas (WRIA 15), Clear/Clarks Creek (WRIA 10), and North Fork Muck Creek (WRIA 11). Relatively little urban development is expected in the eastern portion of the County, much of which is federal land (Mount Rainier NP, National Forest) or commercial timber land.

Ecology has developed TMDLs for about 18 water bodies in unincorporated Pierce County. More than half of these are for temperature and sediment problems in upper White River tributaries that drain commercial timber lands in the eastern part of the County. These streams are outside the area covered by the County's stormwater management program and are not subject to this plan.

Table 4-2. TMDLs in Unincorporated Pierce County

WRIA	Water Body	TMDL Parameters
10	Puyallup River	Ammonia, BOD
10	11 Tributaries to Upper White River	Temperature, Sediment
10	South Prairie Creek	Fecal Coliform, Temperature
11	Ohop Creek	Fecal Coliform
11	Lynch Creek	Fecal Coliform
11	Red Salmon Creek	Fecal Coliform
12	Steilacoom Lake and Chambers Creek	Copper

Ecology has identified approximately 30 water bodies within unincorporated Pierce County that are now listed on the State's §303(d) list as "polluted," based on past exceedances of water quality standards (Table 4-3). Federal regulations require that Ecology develop TMDLs for the listed water bodies. Figures 4-6 through 4-9 show the approximate locations of the "polluted" water bodies within each WRIA. Most of these listings were based on fecal coliform exceedances. Several of the water bodies listed in Table 4-3 have very little drainage area under Pierce County jurisdiction.

[1] Urban development includes these land uses as zoned in Pierce County records: commercial, industrial and residential (medium density, high density and multi family). Low density residential was not considered "urban" for purposes of this project.

Table 4-3. "Polluted" Water Bodies in Unincorporated Pierce County[1, 2, 3]

Water Body	Listed Parameter (Category 5)							
	Fecal	Temp	pH	DO	Phos	NH3	Metals	Other
WRIA 10								
Clarks Creek	x		x					
Clear Creek	x							
Clearwater Creek		x						
Fife Ditch	x			x		x		
Hylebos Creek[4]	x	x						
Lyle Creek		x						
Milky Creek		x						
Puyallup River	x						x	
Scatter Creek[4]		x						
Summit Lake			x					
Swan Creek	x							
Unnamed Creek	x							
Wapato Creek	x			x				
White River[4]	x	x	x					
WRIA 11								
Harts Lake					x			
Mashel River		x						
Nisqually/Drayton Passage	x							
Ohop Creek[5]	x							
Red Salmon Creek[5]	x							
Ohop Lake					x			
WRIA 12								
American Lake					x			x
Chambers Creek	x							
Clover Creek	x	x		x				
North Fork Clover Creek	x							
Spanaway Lake	x							
Steilacoom Lake					x			
WRIA 15								
Huge Creek				x				
Little Minter Creek	x							
Mayo Creek	x	x						
Minter Creek	x			x				
Nisqually/Drayton Passage	x							
North Creek							x	
TOTAL	20	9	3	5	4	1	2	1

[1] Water bodies listed as "Category 5" on Ecology's 2002/2004 303(d) list.
[2] Only water bodies located in, or having influence on, unincorporated Pierce County are listed.
[3] Some water bodies (e.g., Clover Creek) were listed for several different reaches.
[4] Less than 2 percent of basin lies within unincorporated Pierce County.
[5] Ecology established TMDLs for these water bodies in August 2005.

(Note: the following figures are hard-copy inserts to this document)

Figure 4-1 Pierce County Watersheds, WRIAs and Unincorporated Areas

Figure 4-2 WRIA 10 Existing and Potential Urban Land Use in Unincorporated Pierce Co.

Figure 4-3 WRIA 11 Existing and Potential Urban Land Use in Unincorporated Pierce Co.

Figure 4-4 WRIA 12 Existing and Potential Urban Land Use in Unincorporated Pierce Co.

Figure 4-5 WRIA 15 Existing and Potential Urban Land Use in Unincorporated Pierce Co.

Figure 4-6 WRIA 10 Water Bodies with 303(d) Category 5 Listings

Figure 4-7 WRIA 11 Water Bodies with 303(d) Category 5 Listings

Figure 4-8 WRIA 12 Water Bodies with 303(d) Category 5 Listings

Figure 4-9 WRIA 15 Water Bodies with 303(d) Category 5 Listings

5. SAMPLING DESIGN

As described in Section 3, the county-wide monitoring program involves three elements:

- **Long Term Status and Trends (LTT)** monitoring involves benthic invertebrate monitoring, *in situ* bioassays (subject to pilot testing), and physical channel measurements of selected streams to help assess current conditions and identify potential trends over time.

- **Targeted Development (TD)** monitoring involves continuous turbidity and conductivity monitoring and *in situ* bioassays, and physical channel measurements immediately upstream and downstream of stream reaches deemed likely to be affected by major new development.

- **Special Studies (SS)** monitoring provides for additional monitoring, if needed to address data gaps identified by the LTT or TD monitoring, or to support other Pierce County initiatives. SS monitoring could involve the parameters and methods used for the LTT or TD monitoring, toxicity identification evaluation, and/or source tracking studies, depending on the specific data gaps or questions to be addressed.

Table 5-1 summarizes the monitoring program components. Sections 5.1 through 5.3 describe the monitoring locations, parameters, methods and data collection frequencies for each monitoring approach.

TMDL monitoring will be performed on a case-by-case basis. As noted in Section 3, most of the established and pending TMDLs are for fecal coliforms. Appendix F describes the general procedures to be used for monitoring to address fecal coliform TMDL needs.

Table 5-1. Monitoring Program Summary

Program	Scale	Locations	Monitoring suite and frequency						
			B-IBI	In situ bioassay	Channel physical	Continuous turb, cond	Flow/stage	Grab sampling for constituents	Storm event monitoring
LTT	Subbasin	Outlets of subbasins representing 3 levels of development see Table 5-3 (selected existing B-IBI sites)	Annual	1-2X/year (spring if only resident salmonids, spring & fall if resident & anadromous)	Once annually	NA	continuous	NA	NA
TD	development areas & periods (synoptic)	Upstream/downstream pairs to be determined	NA	1-2X/year (spring if only resident salmonids, spring & fall if resident & anadromous)	Annually before/after development & response period	Minimum 2 week synoptic period per quarter	Minimum 2 week synoptic period per quarter	NA	NA
SS	site specific	Site specific based on findings in above programs	If needed	If needed to assess potential toxicity	If needed	If needed to assess water quality trends or "spikes" for specific sources	If needed	For possible correlation with continuous data	If needed to associate potential sources with effects found by other monitoring

LTT-long term status and trend monitoring
TD-targeted development monitoring
SS-special studies monitoring, this could include other monitoring methods in addition to those identified in this table

5.1 Long Term Status and Trend (LTT) Monitoring

5.1.1 LTT Monitoring Overview/Objectives

The purpose of Long Term Status and Trends (LTT) monitoring is to provide data that will help determine if receiving water quality is improving, stable, or degrading in response to existing and future development. The LTT monitoring suite provides a triad of biological, physical and chemical (toxicity) responses that integrate multiple stormwater effects in receiving waters.

5.1.2 LTT Monitoring Site Selection

A random site selection protocol was considered for LTT monitoring because this approach generally allows results to be extrapolated beyond the sampled water bodies. However, County monitoring staff determined that random site selection would be impractical due to legal and physical access limitations and B-IBI sampling site requirements. During the past 10 years, Pierce County has evaluated numerous potential sites for B-IBI sampling, and B-IBI sampling has been performed at more than 80 of those sites. Thus, County staff believes that it has already identified the majority of appropriate and accessible sites within its jurisdiction. Moreover, receiving water quality data at a given location can be affected by a wide variety of factors (e.g., age of development, soils, drainage network, riparian land uses) that are variable and difficult to quantify, thereby limiting extrapolation to other areas. A random approach would be more appropriate for general status and trend evaluation at a much larger scale, such as the greater Puget Sound basin.

Therefore, the candidate LTT monitoring locations were selected based on an evaluation of the more than 80 existing B-IBI sampling stations. The sub-basin draining to each sampling site was delineated and characterized with respect to total area, area under Pierce County jurisdiction, current land use (based on Pierce County tax Parcels), and potential for future urban development (based on Pierce County zoning information). The principal criteria for selecting candidate subbasins for LTT monitoring were subbasin area <10 mi^2 and levels of existing and/or future urban development. Soil type was also considered. However, of the subbasins that met the other criteria, only one has a significant area of glacial outwash soils (types A or B)[2]. Table 5-2 summarizes the LTT monitoring site selection criteria.

Based on these criteria, nine sub-basins were selected as suitable candidates for LTT monitoring (Table 5-3). There are three subbasins representing each of the three general development categories shown in Figure 5-1. Figures 5-2 through 5-6 show the candidate LTT monitoring locations and their associated drainage areas. These candidate subbasins will be reviewed by County staff to verify that the locations and other pertinent information can satisfy the LTT monitoring objectives, or if other candidate subbasins should be identified for LTT monitoring in addition to, or in lieu of, this candidate list.

Table 5-2. LTT Monitoring Site Selection Criteria

Criterion	Rationale
Previously sampled for B-IBI	• Majority of viable B-IBI sites in County have already been sampled • Can use existing data to facilitate trend analysis
Sub-basin area	• Stormwater impacts may be harder to discern in larger basins
% of sub-basin in Pierce County jurisdiction	• Effects of County stormwater discharges and management activities are more likely to be discernible in sub-basins largely under County jurisdiction
Current % urban land use	• Monitoring sub-basins with medium to high % urban land use may help assess efficacy of County's post-development mgt. activities and identify potential retrofit needs
Potential % increase in urban land use	• Rapidly developing areas have greater potential for water quality degradation due to stormwater • Much of County's stormwater management program focuses on prevention of impacts from new development
Surficial geology	• Areas with outwash (vs. till) soils may respond differently to urban development

Table 5-3. LTT Monitoring Locations

Category	WRIA	Basin	Subbasin Stream (B-IBI site#)	Soils
Built Out	10	Clarks/Clear	Squally (19)	Till
Built Out	10	Clarks/Clear	Canyon (20)	Till
Built Out	15	Gig Harbor	Sullivan (77)	Till
Med. Urban	15	Key Peninsula	Lackey (33)	Till
Med. Urban	12	Clover	Clover (80)	Outwash
Med. Urban	11	Muck	Lacamas (65)	Till
Developing	15	Key Peninsula	Vaughan (61)	Till
Developing	15	Key Peninsula	Schoolhouse (KGI, 32)	Till
Developing	15	Key Peninsula	Dutchers (62)	Till

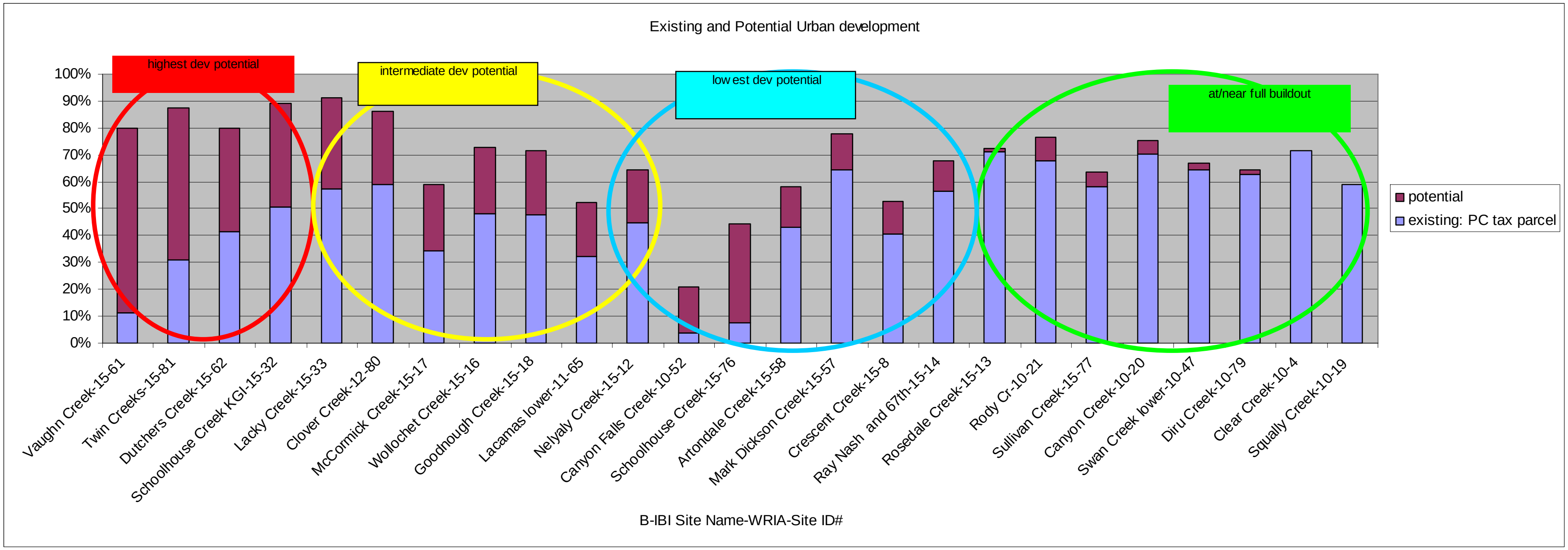

Figure 5-1. LTT Subbasin Development Categories

(Note: the following figures are hard-copy inserts to this document)

Figure 5-2 Clear Creek Subbasins

Figure 5-3 Sullivan Creek Subbasin

Figure 5-4 Clover Creek Subbasin

Figure 5-5 Lacamas Creek Subbasin

Figure 5-6 Key Peninsula Subbasins

Figure 5-7 North Fork Muck Creek Subbasin

5.1.3 LTT Monitoring Parameters and Methods

Benthic invertebrate monitoring, *in-situ* bioassays, and physical channel assessments will be conducted at sampling stations corresponding with each of the nine sub-basins listed in Section 5.1.1.

- Benthic invertebrate sampling will be conducted using the B-IBI methods and associated 10 metric scoring system based on identification to the genus level (except for Chironomids (midges)). Appendix A describes the sampling procedure, which is based on the SalmonWeb protocol (SalmonWeb 2001). Laboratory taxonomic identification will be completed by Aquatic Entomology (Seattle, WA). The B-IBI sampling will begin in the Year One of the monitoring program, and continue with once annual sampling. Sampling will involve three replicates per station with a target minimum of 500 organisms per sample. Where sample sites yield fewer than 500 organisms, collection will include three separate placements of the Surber sampler to yield a composite for each replicate sample.

- *In -situ* bioassays in LTT monitoring locations will be performed on a pilot scale. These tests will be based on the Salmonid ELS/Environment Canada method as modified and adapted by Bailey et al. (2005). These tests characterize rainbow trout (or other salmonid) embryo development through the swim-up fry stage over an exposure period of up to about 60 days. These methods are outlined in Appendix B. The methods may be revised based on the results of the pilot program.

- Hydrologic monitoring will be performed where gages exist near the LTT monitoring stations. These gages have historical records that will be augmented by further monitoring under the CWQMP to develop long term trend metrics that may shed light on stormwater flow controls and support modeling or flood control needs.

- Physical habitat will be characterized in selected stream channel reaches upstream of LTT stations based on the methods of Scholz and Booth (2001). **Error! Reference source not found.** Table 5-4 lists the parameters and measurement methods. Appendix C contains additional details regarding physical channel measurement methods.

5.1.4 LTT Monitoring Frequency

B-IBI monitoring will be conducted once per year, during the late summer through early fall (i.e. August-October), but timed so as to avoid sampling during local salmon runs if present. The *in-situ* bioassays will be conducted in a pilot test with a likely frequency of once or twice per year depending on the presence of resident and/or anadromous salmonids (spring and/or fall). Physical channel measurements will be conducted once annually throughout the monitoring program during the late summer/early fall period, *after* the B-IBI sampling to prevent stream impacts. Streamflow monitoring will be conducted continuously at existing gages corresponding to the LTT monitoring stations.

Table 5-4. Physical Channel Parameters and Measurement Methods

Parameter	Measurement Method
Gradient	Hand level
Shade/Canopy	Gridded mirror (densiometer) or visual estimate
Bank erosion and hardening	Verbal rankings for magnitude, by reach
Large woody debris	Tally no. of pieces >10 ft. long and 10" diameter. Include four numerical zones to identify the location in the stream channel or limit tally to pieces within bankfull channel.
Substrate composition	"Point and count" method with 100 randomly selected grains from upstream side of point bar or channel-spanning riffle.
Pools	Tally and measure the number of pools in a specified reach, using residual depth and wetted channel width to define minimum pool size.
Channel incision ratio	Measure bankfull elevation and height of lowest bank on either side. For pool-riffle or plane-bed channels, measure at riffle. For step-pool or cascade channels, measure at step. Divide lowest bank height by bankfull height.

5.2 Targeted Development (TD) Monitoring-Targeted Development

5.2.1 TD Monitoring Overview/Objectives

The Targeted Development (TD) monitoring will focus on stream reaches deemed likely to be affected by stormwater discharges from new development. It will involve continuous turbidity and conductivity monitoring, *in-situ* bioassays, discharge (stage), rainfall, and physical channel measurements. The TD monitoring will be used to evaluate temporal (i.e. before/after development) and/or spatial (upstream/downstream of a particular discharge) water quality responses between storm and baseflow periods.

5.2.2 TD Monitoring Locations

The TD monitoring will focus on specific development or restoration activities in unincorporated Pierce County. Thus, TD monitoring locations may be located within LTT subbasins or in other subbasins.

At the start of CWQMP implementation, Pierce County Water Programs staff will meet with Planning and Land Services (PALS) staff to identify areas with significant ongoing and near-term development. Water Programs will then query the County's GIS database to delineate the stream reaches likely to be affected by the development activities, the locations of the new development, and the County stormwater drainage systems and outfall locations along each reach.

County staff will review the list and rank the top 10 potential development areas based on 1) whether the area lies in a LTT monitoring subbasin, 2) total area of expected new development, 3) duration of development, 4) presence of an upstream reference site, 5) type of development (commercial, residential, industrial), 6) presence of resident and anadromous salmonids, and other factors as appropriate.

After characterizing and ranking the development areas, target areas will be selected so as to balance resource availability (continuous monitoring equipment and support needed) and provide a desirable level of characterization if many good target sites exist (i.e. stratify among subbasins, development types, durations, etc). Each year during the monitoring program, Water Programs staff will meet with PALS to identify (1) existing sites that can be decommissioned (because the development activity has ended), and (2) new locations where TD monitoring appears to be warranted.

The TD monitoring sites will be located immediately upstream and downstream of the stormwater outfalls affected by development activities. One pair of stations will be monitored for each development area. For example, Figure 5-7 illustrates the North Fork Muck Creek subbasin, which has significant existing and future development potential. One or more pairs of TD monitoring sites could be established in the mid to upper reaches of this subbasin to characterize a particular area of future development.

In some cases, especially for small subbasins, a LTT station may also serve as a TD downstream site. For example, in the Clover Creek subbasin (Figure 5-4), substantial areas of potentially developable land occur within about 1 mile of the lower reach of the stream. Thus, the existing B-IBI station #80 could serve as the downstream station for TD monitoring of this reach of Clover Creek. In all cases, the downstream site should be located to ensure adequate mixing of discharges of interest, but not so far from the discharge that other intervening tributaries or discharges would substantially affect the water quality.

The upstream stations would need to represent adequate hydrologic and hydraulic reference conditions suitable for comparison with the downstream station. The upstream station should be located as near as possible to the discharge(s) of interest and avoid contributions from intervening tributaries or other discharges. In some cases where the targeted development is located high in the watershed, an upstream reference station may not be possible, such as in upper North Fork Muck Creek. See Figure 5-7, which indicates substantial developable land upgradient of the stream's headwaters. In this case, temporal monitoring (i.e. comparisons of data over time at the downstream station) would be the only available option and would be used to indicate before/after water quality responses.

Unlike the LTT monitoring stations, the TD monitoring locations do not yet exist. Therefore, the following factors would need to be taken into account to ensure the TD monitoring stations can be adequately located to represent the discharge and associated receiving water conditions:

> **Intervening flows.** To effectively interpret monitoring data, the presence and effects of intervening flows from tributaries and other discharges that are not the focus of TD monitoring should be minimized or understood when it is not possible to site monitoring locations to avoid them entirely.
>
> **Presence of other monitoring activity.** Certain TD monitoring vicinities and/or locations may already be subject to relevant monitoring by others, such as the South Prairie Creek B-IBI monitoring by EPA. In this case, the location and data generated by the other entity could be used by the County if consistent data items and data quality will be generated and shared over desired time frames. Otherwise, the County will monitor the site.

Practical Limitations:

Legal access. Staff must have legal access to monitoring locations, either through Pierce County rights of way, easements, or specific agreements with property owners where possible (e.g. WSDOT).
Physical access. Staff must have adequate and safe access to monitoring locations.
Adequate hydraulic cross section. In most cases, stage will be sufficient to indicate relative hydrology between storm and baseflows. In other cases, discharge measurement or estimation may be needed. In either case, an adequate hydraulic section is needed and should be characterized (i.e. for stage-discharge curves). Existing gages proximal to the sampling stations may be adequate. In any case, unstable cross sections and those subject to backwatering or side channel diversion/braiding should be avoided where possible.
High water. Certain streams may present high water levels that may restrict access or ability to install onsite equipment.
Vandalism potential. Certain locations may be known or suspected for vandalism. All onsite equipment deployed at any site will have common security measures and inconspicuous installations.
Discharges from other jurisdictions. Some stream reaches within Pierce County receive flows from other jurisdictions. It will be important to understand the type and character of flows that could effect TD monitoring.

5.2.3 TD Monitoring Parameters and Methods

The TD monitoring will involve physical channel assessments and potentially *in-situ* bioassays (depending on the pilot testing outcomes), using the same methods used at the LTT monitoring locations (see Section 5.1.2 above). In addition, water quality probes and data loggers will be installed to monitor receiving water turbidity and conductivity. The probes will be programmed to measure turbidity and conductivity at 15-minute intervals throughout the duration of the monitoring effort. A shorter interval would lead to unnecessary power consumption and lead to more frequent battery renewal needs. It is important to provide the necessary level of QA/QC for these instruments as outlined in Appendix D. Continuous monitoring will be performed using Ecology and USGS protocols, which are outlined in Appendix D.

Discharge monitoring will be used to associate hydraulic/hydrologic and continuous water quality data to examine baseflow and stormflow periods as described in Section 10. Discharge monitoring will be stage only unless specific needs arise that warrant flow rate measurement/estimation. In most cases (i.e. small streams), stage data will be sufficient to distinguish baseflow and stormflow periods. However, larger channels may have sensitive stage-discharge relationships or variable baseflow, in which case site-specific flow rate monitoring methods would be used. Discharge monitoring will involve stage measurement using pressure transducers in the continuous loggers, using the same recording interval as continuous data items (i.e. turbidity and conductivity).

Rainfall monitoring will use existing tipping bucket rain gages in the vicinity of TD monitoring stations, which could include County, NOAA, "SchoolNet[3]" or other loggers. The need to set up a

[3]A number of SchoolNet rain gages are located throughout western Pierce County. County staff may be able to take advantage of real time data acquired via the internet or remote wireless devices (cell phones, PDAs, etc.)

new rainfall logger would have to be justified by the County's level of monitoring interest in the particular target development area. Hourly summaries of fixed interval data logging (i.e. number of tips in 5 minutes) will be needed to best interpret continuous monitoring data collected for TD monitoring.

5.2.4 TD Monitoring Frequency

Ideally, TD monitoring in a given reach should be conducted throughout the duration of the land use activity that triggered the monitoring (e.g., construction of a subdivision or habitat restoration project). Continuous turbidity and conductivity monitoring should encompass the duration of the change in land use activity if possible. In-situ bioassays should be done in the spring and fall of each year (depending on salmonid presence) throughout the duration of the activity. Physical channel characterization should be done at the beginning and end of each TD monitoring effort.

5.3 Special Study (SS) Monitoring

5.3.1 SS Monitoring Overview/Objectives

The Special Studies (SS) monitoring stations would be utilized for adaptive management for investigating the findings of LTT and TD monitoring, for restoration sites, or other needs identified in the future. The methods used would depend on the nature of the findings and issues. Each case of SS monitoring will be documented to provide the rationale for the monitoring, and any adaptations or other monitoring needs warranted by the case.

5.3.2 SS Monitoring Locations

These stations would be selected as needed subject to the general factors listed in 6.2.2. Stations could be located similar to TD monitoring stations by providing upstream/downstream data pairs to determine the presence and degree of influence of a particular discharge. The SS monitoring could also be designed to provide stormwater outfall sampling if the need is indicated by either the LTT or TD monitoring work.

5.3.3 SS Monitoring Parameters and Methods

- SS monitoring could include *in situ* bioassays, continuous monitoring, discharge (stage), or rainfall monitoring as described above, as well as other special studies such as toxicity identification evaluations.

- In SS monitoring, correlation sampling may be used to associate other parameters with turbidity or conductivity. Given a significant correlation, the continuous data can be extended to examine trends in other constituents that are not amendable to continuous sampling, such as TSS. In this case, TSS samples would be collected randomly at SS sampling stations in stormflow and baseflow periods as correlations are expected to be different due to the different suspended sediment particle size distributions in these periods. These samples would be collected from a given number of periods collected at random intervals in these periods. For example, TSS samples would be collected at 10 randomly selected times during each of 4 randomly selected stormflow periods. Baseflow sampling would be less frequent given the anticipated lower variability in TSS compared with stormflows. Correlations between turbidity and other solids-associated constituents could be developed similarly. It may be possible to extend this approach to fecal coliform monitoring, where onsite, rapid sampling methods (i.e. IDEXX Colilert) could be used to determine the potential correlation.

- Episodic sampling and monitoring of receiving waters or stormwater event discharges may be indicated as an adaptive management need under SS monitoring and would be site specific and covered by a separate, brief monitoring plan.

5.3.4 SS Monitoring Frequency

The SS monitoring frequency would be dependent on case-specific needs and documented in a separate plan.

6. DATA QUALITY OBJECTIVES

Data Quality Objectives (DQOs) are qualitative and quantitative measures taken to ensure data support a particular use. The DQOs are related to precision, bias, representativeness, completeness and comparability of data and will be used in this study to assess the quality of the families of data items (BIBI, channel physical character, ELS *in situ* bioassays, and continuous monitoring). These factors are outlined in Table 6-1 and addressed in more detail below. Field and laboratory results will be evaluated to determine if data are acceptable to support the monitoring objectives.

Table 6-1. Data Quality Objectives

Data item	Program(s)	Bias	Precision	Representa-tiveness	Completeness
BIBI	LTT	Target 500 organisms minimum per sample	3 replicates	Target habitat/substrate	Method SOP
Channel - Physical	LTT and TD	Method SOP	Method SOP	Target cross sections and reaches	Method SOP
ELS *in-situ* bioassays[1]	LTT and TD	Minimum control normal development of 70%	4 replicates per sampling station	Minimum control normal development of 70%	Complete Life stages at 7, 20,30,60 day progressions
Continuous WQ	TD	Logger calibration (turb: ±2%/0.3 NTU; cond: ±0.5%) Random check samples	Logger calibration	Target periods	90% complete, 2-week concurrent period per quarter
Streamflow	LTT and TD	Flow meter (stage) calibration	Logger calibration	Target periods	Same as above
Rainfall	TD	Logger calibration	0.01”	Target periods	Same as above

LTT-long term status and trend monitoring program
TD-targeted development monitoring program
[1]ELS in-situ bioassays are subject to a pilot testing program and the DQOs in this table are potential examples that could result from the pilot testing.

Precision: Precision is a measure of the amount of variation in data caused by inherent variability of the particular environmental parameter, and variation in sample collection and measurement. In general, replicate samples/observations will provide a measure of precision. For the B-IBI monitoring, at least three field replicate samples will be collected at each site. According to Appendix A in the *Monitoring Needs Assessment Report* (Brown and Caldwell, 2005), three replicates will yield a minimum detectable difference of about 10 in the B-IBI score, assuming a 2-sided t-test is used (because scores could be expected to increase *or* decrease, especially for the LTT monitoring full build-out subbasins). For the ELS bioassays, the number of replicate installations will be determined by the pilot test. For the continuous monitoring, precision is a function of the equipment used and its calibration status.

Bias: Bias provides a measure of any systematic error in sampling methods and/or analysis. In this study, bias will be measured by targeting a minimum of approximately 500 organisms per sample for the B-IBI (according to the *Monitoring Needs Assessment Report*, Appendix A). In the ELS bioassays, the pilot test will determine appropriate criteria for egg batches, which could include a level of at least 70% normal development in each batch of embryos used in the ELS tests. Continuous monitoring probes will be calibrated according to manufacturer's instructions. In addition, periodic random samples will be used to estimate potential bias for continuous turbidity and conductivity.

Representativeness: Representativeness is a measure of how closely measured results reflect targeted conditions in space and time, and how well the targeted conditions represent the range of possible outcomes. Sampling locations will be selected to best represent each data item. For example, B-IBI sampling requires sampling in an appropriate substrate (gravel) and a minimum number of organisms collected per sample (suggested at 500 per *Monitoring Needs Assessment Report* to ensure all taxa at a site are adequately represented). The *in-situ* bioassays will be deployed near the B-IBI sampling locations (but so as not disturb the substrate to be sampled) so that they can represent the same water quality conditions that the B-IBI organisms experience. Continuous monitoring stations will be selected to prevent the influence of local anomalies such as eddies, backwaters, or pools that would tend to not represent the flowing water conditions at the particular site.

The timing of collecting each data item is also important to represent targeted conditions. The B-IBI sampling will be conducted once per year in the later summer/early fall to ensure sampling captures appropriate life stages present according to the method. For the ELS bioassays the pilot test will determine if multiple seasons can be tested, for example to represent periods when resident and/or anadromous species and multiple life stages would be expected to be present (i.e. fall for anadromous salmonids, and spring if only resident salmonids present, such as cutthroat trout). The pilot test would also develop representativeness criteria for rainfall occurring during each phase of the test. Physical channel measures will be collected every year during the B-IBI sampling periods so that results can be associated with B-IBI data. Continuous monitoring will target data collection throughout the year so that multiple stormflow and baseflow periods can be analyzed at each site and compared with other sites, and with a goal of a 2 week period of concurrent monitoring each quarter to compare site to site responses.

Completeness: Completeness is a measure of the amount of valid data collected relative to the stated work plan objectives. The degree of completeness relates to the ability to make appropriate analyses and conclusions. To prevent data gaps and provide for trend analysis, the B-IBI samples have a goal of one sample per year (as limited by the method, but subject to other DQOs to ensure representativeness). For the ELS bioassays, the pilot test will develop completeness goals, which could include seasonality (species and life stages) and exposure periods (which of the multiple life stages the test should encompass). Physical channel data set completeness goals are to cover at least 3 of the 5 years of the permit (e.g. years 1, 3, and 5). Continuous monitoring should be conducted to provide valid data without significant gaps during baseflow and stormflow periods and to provide at least one synoptic data coverage period of two weeks per quarter covering all stations (to address site to site variability and responses.)

Comparability: Comparability relates to LTT data over time and TD data over space and time. Data comparability expresses the confidence that data groups can be compared with others over time and space. Comparability will be maintained by use of consistent sampling procedures, sampling locations, equipment calibration, consistent units and data collection forms to ensure key information is collected supporting each field data collection period. To reach appropriate conclusions about the differences in data from paired TD stations, the monitoring periods and hydrograph characteristics should be as similar as possible (each station's monitoring period should represent the same hydrographic stage(s) or fraction thereof, i.e. the rising, peak, and falling limbs).

7. FIELD ACTIVITIES

Field activities include sampling station set up, equipment deployment, data collection, maintenance and demobilization as needed for the B-IBI, ELS bioassay pilot test, physical channel, streamflow gaging and continuous monitoring as outlined below. All field work will be conducted for these needs according to Appendices A-D. Field work needed for TMDL monitoring would be developed for each water body, and when the MST method is used, field work would be based on the methods described in Appendix F.

7.1 B-IBI Sampling

The annual B-IBI sampling for the LTT monitoring should be completed before the physical channel measurements so that stream disturbance is minimized before invertebrates are collected. Field work involves an annual visit (August-October, before any local salmon runs begin) to each sampling site and collection of 3 replicate samples of benthic invertebrates. These organisms are collected by disturbing the substrate to dislodge resident organisms and trap them in a net placed downstream.

Each sample of organisms is collected using a Surber sampler and placed in an appropriate sample container with preservative (alcohol; isopropyl or ethanol), labeled and stored for shipment to the contractor analyzing the samples.

According to the Needs Assessment Report (BC, 2005), each sample should contain a target minimum of 500 organisms. Where sample sites yield fewer than 500 organisms, collection will include three separate placements of the Surber sampler to yield a composite for each replicate sample. Thus, at least 27 samples will be collected each year (9 sites with 3 replicates each site). An outline of sampling methods, equipment needs and the field data sheet are in Appendix A.

7.2 ELS In-Situ Bioassays

The ELS *in-situ* bioassays will first be conducted on a pilot scale. If the pilot scale testing indicates that the ELS will provide useful information for the County's stormwater management program, ELS monitoring may be conducted at additional LTT, TD, and/or SS stations,. Initial field work would be completed to locate the best places for the test cages and determine availability and suitability for onsite substrate (i.e. gravel) to anchor and camouflage each test cage. The pilot test will determine the number of replicate installations to be used at each monitoring site. Appendix B contains an outline of the current concept of the ELS *in-situ* procedures that will be subject to the pilot test.

For each anticipated deployment period, the gamete supplier must be contacted in advance to determine supply and relative egg quality. The supplier will then indicate which days/dates gametes are available. Once obtained, eggs are fertilized according to the method SOP (Appendix B) and placed into containers for transport to the deployment sites. Eggs are then placed in hatch boxes, loaded into wire cages and anchored/covered with gravel. Field staff then must note site conditions and log site data on the field forms, including measurement of pH, temperature, DO and conductivity. The support lab runs the 7-day embryo development control to determine that the particular batch of eggs is of good quality.

7.3 Physical Channel Measurements

The physical channel measurements will be recorded annually in the field using field data sheets. For LTT stations, these recordings should be collected within one month of the associated B-IBI sampling (late summer/early fall) and should be completed after the B-IBI sampling so that the stream is not disturbed before invertebrates are collected.

7.4 Streamflow monitoring

Existing stream gages maintained by Pierce County will be used in the LTT monitoring program. These gages need to be downloaded periodically, with maintenance and calibration performed as needed. The existing frequency of this servicing should be evaluated to determine if any changes are needed. Stage-discharge curves may need to be updated or recalibrated if cross sections change or other conditions warrant. These updates are based on current meter surveys at channel control sections. Data downloading and archiving procedures will be evaluated and further developed under the EDMS procedures as needed. These procedures should follow the USGS methods where appropriate for documenting gaging stations, establishing channel cross sections, current meter surveys, calibration, and flow data record validation and establishment.

7.5 Continuous Monitoring

Continuous monitoring fieldwork needs include initial deployment, periodic maintenance, and equipment demobilization at each TD monitoring site. Details on field site selection, installation, inspections and maintenance are found in Appendix D which contains the USGS method guidelines. Because most, if not all, TD monitoring locations are expected to be located in small streams, the USGS methods for assessing cross sectional variation are not expected to be needed (assuming downstream TD monitoring sites can be located to ensure complete mixing of the upstream discharge(s) of interest).

Each monitoring station should be inspected prior to initial deployment to determine site installation needs, including anchoring and potential vandalism issues warranting some form of camouflage or other means of deterring theft or damage. The presence of high voltage wires, radio towers or airport lighting systems may cause EMI that can interfere with data collection. Installation sites should be selected to be represent flowing water conditions at all stages, and thus be free of backwater at baseflow and stormflow conditions, out of eddies and potential scour or deposition areas. For stations using stage measurement, a benchmark or other suitable reference point (such as a survey pin, stake or available onsite permanent object) will be located to serve as a hydraulic datum for the site and defined as either a tape-down or zero set point. Site installation information will be recorded on field sheet #1, including photograph(s) to identify the site for future reference.

For each deployment, the equipment should be calibrated in the laboratory per manufacturer's instructions. Each deployment will have a field data log (field sheet #2) to ensure all factors are considered and associated data are collected, including photographs to note any significant conditions or changes from the initial reconnaissance.

Subsequent maintenance will include once-monthly site visits to inspect, download, maintain and re-calibrate each instrument as needed. Use field data sheet #3 to note any conditions that could have influenced the data quality, including changes in channel morphology, bed conditions, backwater, debris, vandalism, etc. These inspections should also include a brief reconnaissance of upstream portions of the stream and/or particular development activity under TD monitoring to note evidence of any activities that could explain observed changes in monitoring data. Verification readings of turbidity and conductivity should be taken by a handheld unit, and stage recorded. These readings should be taken before, during and after servicing the unit to document any changes during the service interval. Each unit should be inspected for potential biofouling or sediment accumulation on the sensors. If units are not within the manufacturer's calibration criteria, they should be removed for servicing and a calibrated unit substituted if available. Data will be downloaded using a laptop or OEM unit. Data correction, if warranted, can be performed according to the USGS methods of Appendix D.

Upon completion of TD monitoring at each site, the equipment will be demobilized, cleaned and reconditioned as needed for storage or deployment elsewhere. Field data sheets will be stored by site.

7.6 SS Monitoring Surrogate Sampling

If deemed necessary, random sampling would be used during stormflow (most frequent) and baseflow (less frequent) to develop correlations between grab samples for TSS and continuously logged turbidity. The grab sampling timing and data logging clocks would need to be synchronized. This sampling would site specific, and may be done for sites indicated by LTT or TD monitoring results or other areas selected by the County. Other parameters may be added as needed, including bacteria or nutrients.

8. LABORATORY PROCEDURES

Laboratory analyses are required for the B-IBI, correlation/surrogate sampling under SS monitoring (i.e. TSS vs. turbidity), and for relevant controls of the ELS *in-situ* bioassays as determined appropriate in the pilot test (Appendix B).

The B-IBI analyses will be performed by a contract lab (Aquatic Biology Associates, Corvallis, OR) using their standard operating procedure, which is based on an EPA method.

Lab analysis for TSS will use method EPA 160.3 using standard laboratory QC (duplicates, matrix spikes, blanks and check standards). A minimum sample volume of one liter should be collected and analyzed by the laboratory. In the event of elevated TSS that prevents laboratory filtration of the entire one liter sample, the volume filtered should be indicated in the sample results. If elected, other surrogate sampling may be warranted and would be covered by a separate, brief monitoring plan.

9. QUALITY CONTROL

As indicated in Section 5, QA/QC needs apply mostly to field sampling and data collection, where details are specified in the respective Appendices. Standard laboratory QC will be applied for the TSS surrogate sampling for SS monitoring sites.

This section to be completed

10. DATA MANAGEMENT, EVALUATION AND REPORTING

Data will be collected according to the frequencies described in the preceding sections and evaluated and reported for each respective program as described below. Data reduction will synthesize data from multiple monitoring programs and other related County programs (e.g. construction, roads maintenance) where appropriate. Periodic data review will be used to determine follow up work, including more focused monitoring to elucidate particular cause and effect relationships, management actions, etc. Annual reporting and synthesis of data from each program will be used for long term trend analysis.

Data management will use an environmental data management system (EDMS) that Pierce County is now developing to support this monitoring program. This CWQMP will be updated as needed once the EDMS is operational. This EDMS will refine existing data collection and management procedures and integrate the data generated under this CWQMP. It is anticipated that the EDMS will provide for all data generated by the CWQMP and other existing, pertinent programs. The EDMS is anticipated to provide for periodic standard reports as well as certain user-defined queries. The standard reports will be generated periodically to provide status of the multiple data types under the CWQMP as outlined below. The data evaluation and reporting for the ELS *in-situ* bioassays will be developed during the pilot testing and is not outlined below.

10.1 Stream Channel Physical Habitat

Physical stream channel conditions and trends will be evaluated using the guidelines described in Scholz and Booth (2001). The measurement of physical stream conditions data will be used to aid in the interpretation of biological monitoring results (B-IBI). To facilitate comparisons and trend analysis, the results may be used to calculate a multi-metric index, such as the physical stream conditions index (PSCI) scores (McBride and Booth 2005).

10.2 Biological (B-IBI) Monitoring

The B-IBI monitoring data will be summarized annually and examined for obvious temporal and spatial trends in successive years sampling. Data reduction methods will be consistent with the method and include the 10 summary metrics that are calculated from data collected at each sampling location. Three levels of data assessment will be used: composite score, the 10 metrics, and interpretation of any obvious patterns of improvement or degradation in the individual metrics or taxa data. The method will be based on the 10 metric B-IBI, assuming organisms can be adequately classified to the genus level.

According to the Appendix A in the *Monitoring Needs Assessment Report*, collecting three replicates per this plan will yield a minimum detectable difference (MDD) of about 10 in the B-IBI score, assuming a 2-sided t-test is used (because scores could be expected to increase ***or*** decrease, especially for the LTT monitoring full build-out subbasins). Thus given the scores can range from 10 (worst) to 50 (best), the 3 replicates could detect approximately four categories of biological condition. Historical data will be synthesized with data collected under this QAPP where appropriate.

When the B-IBI data for a particular metric indicates a significant trend (i.e., drop in score of about 10 or more over multiple years), the USEPA's Stressor Identification (SI) Guidance methods will be used to aid evaluations of potential causes and effects, particularly to distinguish between potential chemical and physical causes or combinations thereof. See Figure 10-1 for the SI framework.

The stream channel physical habitat data will be useful in the SI process, as physical stressors (i.e. flow and sediments) are commonly principal, if not sole causes of effects on benthic macroinvertebrates. In addition, if the SI process indicates that a toxicant may be causing or associated with a particular biological effect, SS monitoring (e.g. episodic receiving water and/or stormwater sampling) may need to be triggered. See Figure 10-2 and Figure 10-3 for example causal analysis pathways that could be used for these two families of stressors (USEPA 2003).

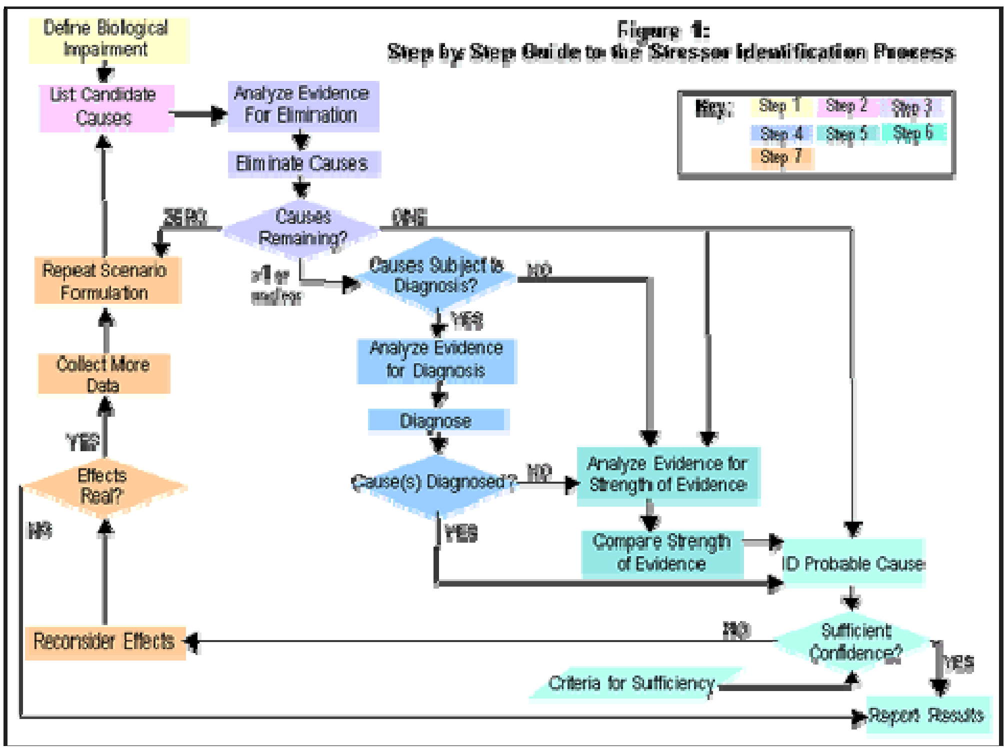

Figure 10-1. The Stressor Identification Process (EPA 2003)

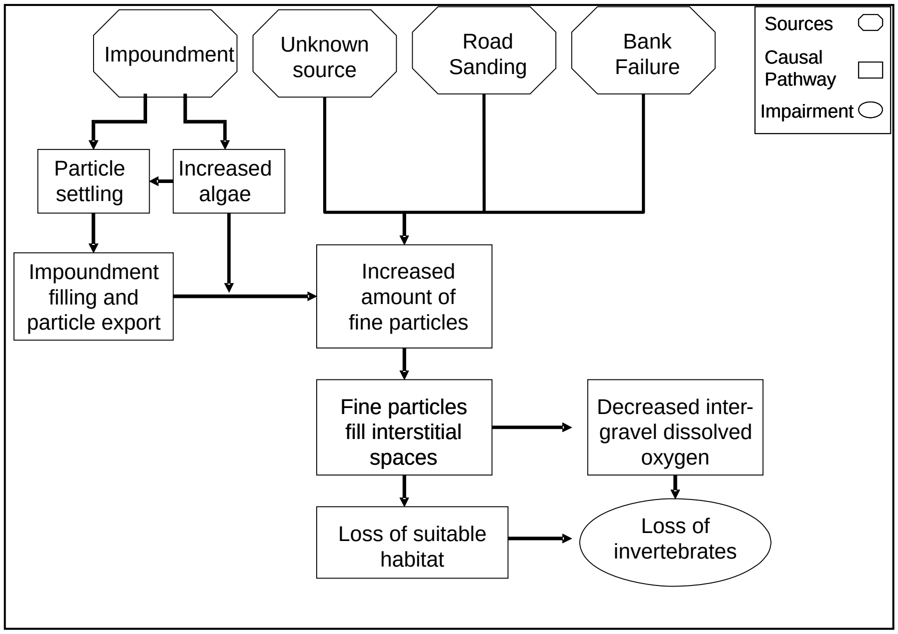

Figure 10-2. Example causal analysis for biological impact of fine sediments (EPA 2003)

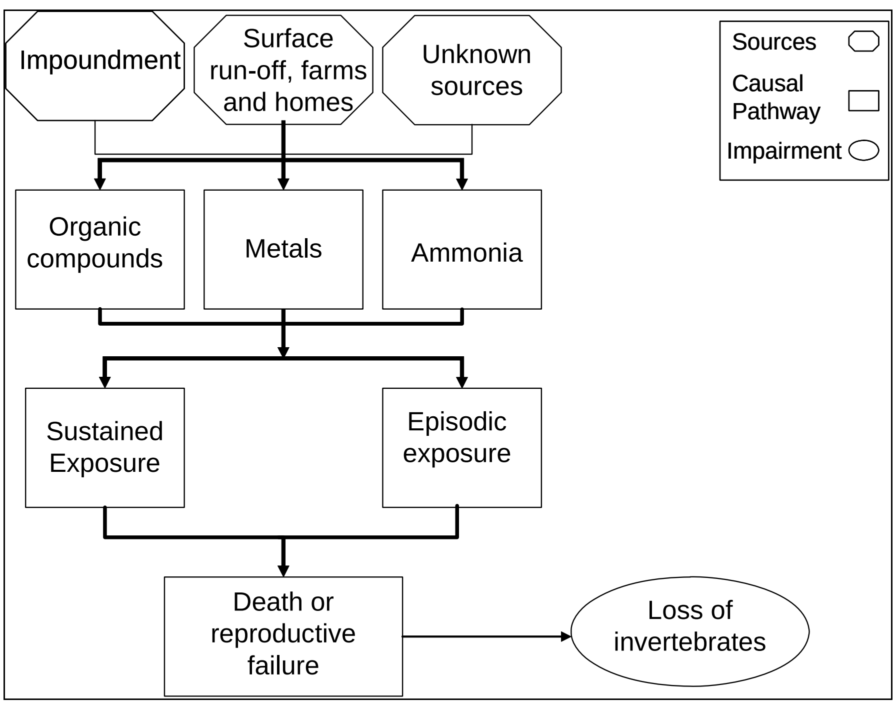

Figure 10-3. Example causal analysis for biological impact of toxicants (EPA 2003)

10.3 Hydrologic (Streamflow) Monitoring

Streamflow data can be used to compute certain metrics that estimate the potential hydrologic impacts of urbanization. Booth et al. (2004) found that two metrics "succeeded in capturing the hydrologic effects of urbanization, despite local variability in soils, geology, and watershed topography among Puget Sound lowland basins." These metrics are the average annual fraction of a year that the mean daily streamflow exceeds the mean annual flow (T_{Qmean}), and the fraction of the time streamflow exceeds the 0.5 year flood ($T_{0.5yr}$). These metrics should be evaluated about every five years to discern trends and determine their statistical significance. However, given the typical variability of streamflow in this region, flow monitoring may need to be conducted for many years in order to support meaningful analysis of hydrologic trends.

10.4 Continuous Monitoring

The continuous monitoring data will be summarized at various frequencies as needed through the monitoring program. Initial evaluation frequencies in the first year should include weekly for the first one to two quarters for verifying that equipment is performing effectively, then monthly, with an annual review each year. Episodic data evaluation may be elected under certain conditions of interest, e.g. early fall storms, unusual events of high rainfall/duration/intensity. Evaluation frequencies in successive years will be at least quarterly or otherwise as determined based on first year findings and other information that would relate to data review needs for specific locations, e.g. as new development occurs or other major changes that would be prudent to monitor. Continuous monitoring data reduction methods and corresponding metrics include the following items.

10.4.1 Data Validation

The processing of continuous monitoring data records should be completed frequently enough to allow correction of field problems as needed. Initial inspections and data downloading and validation should be conducted every 2 weeks for the first 2 to 4 months after deployment, then monthly for the duration of the program. Field notes will be reviewed to determine potential causes and need for data correction. Data will be corrected according to the USGS methods in Appendix D when causes of errors can be explained (e.g. sensor drift, biofouling, sedimentation, power loss, EMI, etc).

10.4.2 Concurrent Data Items

To identify and distinguish periods of stormwater discharge from baseflow or potential dry-weather discharges, rainfall and discharge data should be collected concurrently with continuous water quality data. Each of the following data evaluations should include this concurrent supporting data.

- **Comparing period averages for different hydrologic regimes, i.e. stormflow and baseflow.** For example, the ratio of storm to baseflow turbidity and conductivity for periods of interest such as seasons, months, weeks, or rainfall events. Stormflows would be expected to scour and transport solids that would result in elevated turbidity compared with baseflow periods, resulting in ratios >1. In contrast, conductivity would be expected to be higher in baseflow than during stormflows (groundwater-dominated baseflows are typically higher conductivity than typical urban runoff (Marsh, 1987; Morisawa 1968; Walling and Webb, 1980;

Tomlinson and De Carlo, 2003; Irvine, 2003). Stormflow to baseflow conductivity ratios >1 tend to indicate the potential presence of dissolved constituents from non-stormwater discharges that could be used with other evidence (e.g. visual indicators) to trigger IDDE activities.

- **Temporal comparisons of the above ratios.** A significant spike or trend in magnitude in these ratios over time at a particular location could indicate further assessment or management needs. For example, average turbidity during multiple storm events of interest could be compared with antecedent baseflow turbidity.

- **Spatial comparisons of the above ratios for similar conditions among subbasins**. The relative magnitudes of the spikes can be used to indicate management and further assessment activity needs among subbasins. For example, a particular subbasin may be generating a stronger turbidity response than others and would be prioritized for follow up actions.

- **Within-event time series**. Where indicated, particular events would have time-series data examined for obvious patterns.

- For turbidity, the above information can be used to identify potential sources. For example, it would be important to distinguish the presence and degree of sediment imported from discharges versus bank failures or channel scour. This information would ensure that appropriate actions could be determined and focused for relevant discharges and/or stream reaches. An absence of stormwater discharges between stations experiencing significant increases in turbidity could indicate bank failure, or local scour occurring in the channel.

- **Surrogate monitoring**. To provide for suspended sediment estimation, a surrogate approach will be used where needed under SS monitoring to correlate turbidity with suspended sediment. Where the correlation is significant, it can be used to estimate TSS concentrations, loads and time series and averages for use in the above data evaluation approaches where needed. The USGS has used this approach effectively in several ongoing studies, finding that 2 years of data collection were sufficient (about 35 to 55 samples) to define the relation between the constituent and its surrogate (USGS, 2000). This approach could be extended to other parameters expected to be significantly correlated with suspended sediment, such as metals, nutrients, bacteria. These correlations would most likely need to be established for each site but could be applied broadly if the data indicate it is appropriate. See section 5.3.3 that describes the TSS/turbidity correlation sampling approach.

10.5 ELS In-Situ Bioassays

Receiving water (ambient) bioassays will be preformed *in-situ* based on the pilot test using the ELS/Environment Canada method as modified and adapted by Elphick and Bailey (2005). Data evaluation is outlined in Appendix B and subject to pilot testing.

10.6 Storm Event Sampling and Monitoring

Episodic sampling (storm events) will be used as a SS monitoring adaptive management tool, triggered when and where needed as indicated by the LTT or TD monitoring programs. For example, if ratios of storm to baseflow turbidity are significantly different between two stream monitoring stations, stormwater discharges in certain locales could be sampled episodically to identify a particular outfall responsible. Chemical and/or toxicity sampling of stormwater would be triggered if the B-IBI and SI analysis indicates the need. Toxicity monitoring could be focused on episodic or longer term periods, and would need use appropriate sampling methods, organisms and toxicity investigation and evaluation (TIE) methods for the relevant site of interest. Any stormwater discharge toxicity testing will be developed under an addendum to this QAPP if and when needed. Indications of potential illicit discharges would be handled under other County programs.

10.7 TMDL Monitoring and Evaluation

Particular waters affected by a TMDL will be monitored and evaluated under a separate plan(s). Where appropriate, the LTT, TD, SS and TMDL monitoring programs can integrate data, for example, in annual monitoring program reports and/or the SI process for B-IBI effects investigations and evaluations.

10.8 Reporting

Reports will be generated annually to provide the status of the LTT and TD monitoring work, pertinent metrics and identify any obvious issues. Long term trend analysis will be reported once every five years.

In addition, for the TD continuous monitoring, more frequent data summaries can take advantage of the continuous data collection. These summary reports could be monthly, quarterly or another basis depending on site-specific needs.

11. REFERENCES

(to be completed)

Ecology 2005

Woodward-Clyde 1998

URS and Brown and Caldwell 2004

Whiley and Walter 1997

Karr and Chu 1999

NRC 2001

U.S. EPA 2002

Scholz and Booth 2001

Fore 2004

SalmonWeb 2001

Bailey et al, 2005

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Horner et al. 1997

Burton and Pitt 2001

Ankorn 2003

Uhrich 2002

Eads and Lewis 2002

Packman et al. 1999

Center for Watershed Protection 2003

Ecology 2005

BC, 2005 *Monitoring Needs Assessment Report*

Booth et al. 2004

Marsh, 1987

EPA 2003

Morisawa 1968

Walling and Webb, 1980

Tomlinson and De Carlo, 2003

Irvine, 2003

McBride and Booth 2005

USGS, 2000

12. GLOSSARY

BMP-best management practice

DIP-detailed implementation plan

CWQMP-countywide water quality monitoring plan

ELS-early life stages

LTT-long term status and trends monitoring program

MS4-municipal separate storm sewer system

MST-microbial source tracking

NPDES-national pollutant discharge elimination system

QAPP-quality assurance project plan

SS-special studies and adaptive management monitoring program

TD-targeted development monitoring program

TMDL-total maximum dail load

TSS-total suspended solids

APPENDIX A

Standard Operating Procedures for B-IBI Sampling

Source: Salmon Web (derived from Karr)

Checklist of materials:

___ Meter tape to identify location
___ 500 micron mesh Surber sampler
___ (2) 500 micron mesh sieve (or smaller)
___ Waders (for each person)
___ Flagged weight to identify sample location
___ Isopropyl alcohol, Technical grade (99+%)
___ 1-liter squirt bottle for isopropyl alcohol; second bottle to refill the first
____Vegetable or dish & pot scrubbing brush (plastic) with 6-8" handle. Brass or wire brushes will mangle invertebrates, and should not be used.
___ Garden trowel to disturb substrate
___ Stop watch
___ (2) White buckets to empty sample from Surber
___ Large cup with handle to rinse invertebrates off Surber
___ Forceps (Tweezers)
___ Plastic spatula
___ Waterproof ("Rite-in-the-rain") paper
___ Pencil, permanent marker (Sharpie), and grease pencil
___ Screw-top vials
___ Ziploc bags
___ Camera

Sampling Protocol for Benthic Invertebrates

<u>Select site</u>

Locate stream reach to be sampled. Find a riffle (fast moving water over rock or cobble substrate, surface water should be broken) near the middle part of the stream. Riffle should be long enough to accommodate three replicate samples. Ideal sampling locations consist of rocks 5 to 10 cm in diameter sitting on top of pebbles. Substrates dominated by rocks larger than 50 cm in diameter should be avoided.

Sample within main flow of the stream. Sample at water depths of 10 to 40 cm. Depth, flow and substrate type should be similar for the three replicate samples collected in the riffle. Begin sampling downstream and proceed upstream for the three replicates. Avoid bridges and other large human-made structural features.

If unavoidable, sample at least 50 meters upstream of a bridge and 200 meters (more would be better) downstream of a bridge.

Write down the exact location of the sample site. Use meter tape to measure distance from nearest landmark.

Collect invertebrates

Sampling teams may range from 2 to 4 people. Actual collection of macroinvertebrates requires 2 people. Others can assist with equipment, labeling collections and other duties.

1. Place Surber sampler on the selected spot with the opening of the nylon net facing upstream. Brace the frame and hold it firmly on the creek bottom.

2. Lift the larger rocks resting within the frame and brush off crawling or attached loosely organisms so that they drift into the net. After "cleaning" the rocks, place them in a bucket.

3. Once the larger rocks are removed, disturb the substrate vigorously with a trowel or large spike for 60 seconds. This disturbance should extend to a depth of about 10 cm to loosen organisms in the interstitial spaces, washing them into the net.

4. Lift Surber out of the water: Tilt the net up and out of the water while keeping the open end upstream. This helps to wash the organisms into the receptacle. Drop a piece of weighted flagging tape to mark the location of the first replicate sample.

5. On the creek bank, empty contents of Surber into large bucket. Rinse Surber and empty into bucket until all animals are removed. Great care should be taken in this step to collect and preserve all organisms from the Surber sampler as well as from the rocks and water in the bucket. Use of a magnifying glass and tweezers is essential. Rinse bucket through sieve to remove water from sample. Pick out large debris (sticks and leaves) after carefully removing any invertebrates.

Archive sample

Use spatula to move sample from sieve into a plastic vial. Fill vial to the top with isopropyl alcohol. Put label on inside of vial with name of sampler, date, location, and replicate number. Write location and date on top of vial lid. Place vial in a Ziploc bag labeled with the same information.

Collect replicate samples

Return to the location of the first sample, walk upstream and collect another sample of invertebrates. Leave another flagged marker and process the sample as above. Repeat this process once more for a total of three replicate samples from each site location. Each replicate should be labeled (e.g., #1, #2, #3) and archived separately.

B-IBI Sampling Site Description Form

Date ___________________________ (day/month/year)

Site Location

City______________________________ State____________________________

Watershed______________________________ Stream____________________________

Weather ___ Sunny ___ Cloudy ___ Partly Cloudy ___ Raining ___ Foggy

Longitude ________degrees __________minutes __________seconds

Latitude __________degrees __________minutes __________seconds

USGS map used _________________________(include height and width scale)
____

Elevation __________________(Meters)

Land Uses ___ Urban ___ Suburban ___ Agricultural ___ Grazing ___ Forest

Channelized ___ Yes ___ No

Culverts

Upstream ___ No ___ Yes Approx. distance from sampling site_____________(Meters)

Downstream ___ No ___ Yes Approx. distance from sampling site _____________(Meters)

Dams

Upstream ___ No ___ Yes Approx. distance from sampling site___________(Meters)

Downstream ___ No ___ Yes Approx. distance from sampling site ___________(Meters)

Inorganic substrate ___ Boulders ___ Rubble ___ Gravel ___ Sand ___ Silt ___ Clay

Embeddedness __________________(%)

Sediment __________________(%)

Organic substrate ___ Mud/Muck ___ Detritus ___ Logs/Limbs ___ Pulpy Peat ___ Fibrous Peat

Bank Slope ___ Steep ___ Moderate ___ Slight ___ Other __________________________

Bank Stability ___ Stable ___ Slightly Eroded ___ Moderately Eroded ___ Severely Eroded

Bank Material ___ Clay ___ Rock ___ Dirt ___ Mud ___ Stones ___ Other____________________

Bank Vegetation

___ Barren ___ Grasses ___ Herbaceous ___ Brush ___ Deciduous

___ Evergreen ___ Other ___________________

Stream Shading _________________(%)

Channel cross-section

___ Rectangular ___ U-Shaped ___ V-shaped ___ W-Shaped ___ Other___________________

Undercut Banks ___ No ___ Yes

Air Temperature _________________(C)

Water Temperature (at site)_________________(C)

Water Temperature (1 mile upstream) _________________(C)

Surface Oils ___ None ___ Some ___ Lots

Water Odors ___ Normal ___ Sewage ___ Petroleum ___ Chemical ___ Other__________

Stream Width (at sampling site) _________________(Meters)

Surface Velocity _________________(Meters/second)

Water Depth _________________(Meters)

Riffle Length _________________(Meters)

Riffle Width _________________(Meters)

Distance between replicates within riffle _________________(Meters)

Additional Notes on this form

Document below any information or observations you made that are not included.

Appendix B

Proposed Standard Operating Procedures for ELS In-Situ Bioassays

Background

The *in situ* salmonid early life stages (ELS) tests can characterize salmonid (e.g. rainbow trout) embryo development over periods of up to about 60 days (depending on temperature), and have been used successfully in British Columbia, Canada (Bailey et al., 2005). These tests are based on laboratory methods used for ELS testing (USEPA and ASTM methods). Moreover, the ELS *in situ* testing could target seasonal spawning periods of local species of interest: fall (e.g., chum, coho), spring (e.g., rainbow and cutthroat trout), and therefore, would be highly relevant in terms of applying the results to local streams. This testing will be conducted first on a pilot scale to determine appropriate methods and implementation needs for future application in this CWQMP on a broader scale. The table below and following sections outline the potential testing periods, metrics and procedures.

Table B-1: Test durations, life stages and associated metrics

Phase	Duration (days)	Metric(s)	Comment
Embryo development (E-test)	7	% normal development	Fertilization done in controlled (i.e. lab) conditions or on-site. This is minimum exposure period. Tests would need enough embryos to allow sacrifice of sufficient number to measure the 7-day development, while allowing the rest to continue to progressive stages below
Eyed embryo	20	% normal development	First of 3 progressive exposure periods
Hatch	30	% hatch % normal development	Second of 3 progressive exposure periods
Swim up	60	% normal development, survival, length, weight, contaminant body burdens	Third of 3 progressive exposure periods

Procedure Concept

This method would involve the following steps (this outline will be further developed based on pilot scale testing outcomes):

a) Site setup/preparation
   i) screen and select sampling locations; try to locate them in the same area/reach as the B-IBI sampling sites, but in such a way as to not interfere with B-IBI sampling. For TD monitoring, site selection will need to meet general criteria.
   ii) procure materials
      (1) sampling enclosures (wire mesh baskets used for barbequing chicken, available from a hardware store)
      (2) substrate (gravel) as needed based on site availability
      (3) hatch boxes (Federation of Fly Fishers, modified to prevent escape of hatched fish)
      (4) inconspicuous markers if needed
b) test preparation
   i) notify support laboratory and/or gamete supplier
   ii) define gamete supply windows
   iii) plan and determine deployment periods based on gamete supply and holding times
   iv) acquire gametes (eggs, sperm)
   v) perform controlled fertilization (done by support lab until training sufficient to transition to 3rd party)
   vi) lab begins egg batch validation control tests (fertilization/embryo development)
   vii) store fertilized eggs in containers for travel to field sites
c) deployment
   i) arrive at sites with materials, supplies and fertilized gametes
   ii) place 30 embryos in each of 4 boxes
   iii) close boxes and install in wire cages
   iv) add onsite or imported gravel substrate as needed to fill wire cage and provide overall weight and make inconspicuous
   v) measure and collect deployment data: date, time, weather, air and water temp, pH, conductivity, DO if available
d) first visit (day 20)
   i) remove hatch boxes from gravels/cages
   ii) record observations of metrics in field sheet
   iii) replace hatch boxes in gravels/cages
   iv) measure and collect deployment data: date, time, weather, air and water temp, pH, conductivity, DO if available
e) second visit (day 30); same as first visit
f) third visit (day 60); same as first visit
   i) collect fry in sample container, put on ice in cooler
   ii) remove wire cages and any other material to decommission site
g) re-start testing as needed
   i) in the event an invalid egg batch control occurs at day 7 as indicted by support lab personnel, restart the tests as needed
   ii) arrive at test sites, record any pertinent observations unrelated to the test, i.e. sedimentation, debris, etc that would indicate other needs.
   iii) remove and clean hatch boxes as necessary

iv) begin again with deployment steps described above.

Data recording and metrics

At each of the site visits, record information in field data sheets pertaining to the metrics in Table 1, site water quality measurements (temperature, pH, DO, conductivity), and observations of sediment, debris, etc as indicated in field data sheet.

QA/QC

1. Test validation. Support lab will run egg batch validation tests using the full 7-day embryo development in lab conditions. Minimum normal development will be 70% to validate egg batches and allow field-deployed tests to continue. Development at less than 70% will trigger a recall/restart of all field-deployed tests unless special consideration is given to marginal conditions when/where warranted.

2. Lab replicates: lab controls will have 4 replicates

3. Field replicates: field sites will have 4 replicate hatch box installations per site

4. will consider running parallel lab exposure throughout duration of field exposures

References

BCWLAP. 2003. British Columbia Field Sampling Manual: 2003. For Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment and Biological Samples. British Columbia Ministry of Water Land and Air Protection.

Environment Canada, 1998. Environment Canada, Pacific Environmental Science Center, Environmental Toxicology Section, EPS 1/RM/28 Second Edition, 1998

Appendix C

Standard Operating Procedures for Channel Physical Characteristics

(TO BE COMPLETED)

Appendix D

Standard Operating Procedures for Continuous Monitoring

Please refer to the following document for this SOP.

Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting

By Richard J. Wagner, Harold C. Mattraw, George F. Ritz, and Brett A. Smith

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 00–4252

Appendix E

Standard Operating Procedures for Manual Water Sampling

(TO BE COMPLETED)

Appendix F

Standard Operating Procedures for MST Fecal Coliform TMDL Monitoring

1. INTRODUCTION

This appendix describes the sampling design, field, laboratory, and data evaluation procedures for the Microbial Source Tracking (MST) method developed by Dr. Mansour Samadpour. The MST method may be used for monitoring related to fecal coliform TMDL and Detailed Implementation Plan (DIP) development. Alternatively, simple site inspections to identify obvious bacteria sources may suffice depending on the particular stream and/or site and these methods will be covered in separate documentation. The general approach for the MST method involves (1) measurement of fecal coliform bacteria concentrations, and (2) identification of the associated bacteria sources using "genetic fingerprints".

The MST "genetic fingerprinting" involves isolating *E. coli* ribotype strains from water samples, and matching these ribotypes to one of the approximately 120,000 *E. coli* strains in a "library" of source ribotypes (e.g., human, canine, feline, rodent, avian, equine, bovine, rabbit, raccoon). The MST method has been used to successfully identify the sources of fecal pollution in more than 80 studies throughout North America.

Samples will be collected from the basin outlet as well as upstream locations selected to bracket the potential sources. Sampling will be performed at least once per month over a minimum of one year. Sampling dates will be adjusted as needed to ensure that wet and dry weather conditions are sampled. Supplementary sampling may be performed at intermediate locations (stormwater outfalls or other tributaries) to track pollutant sources affecting specific reaches.

2. SELECTION OF SAMPLING LOCATIONS AND FREQUENCY

2.1 Existing Data Review

Existing data should be reviewed to gain an understanding of potential fecal coliform sources and transport pathways to the affected receiving water body. The following information should be reviewed if available:

- TMDL studies
- Nonpoint source control/watershed action plans
- USGS flow, water quality, and hydrogeology data
- Land use (including potential "hotspots" such as dairies, duck ponds)
- Potential locations of physical (e.g., road crossings) and legal (e.g., publicly-owned lands) access to water body

- Natural and man-made drainage systems (including dry wells)
- Septic system surveys
- Other water quality data that may be available

Based on the existing data, tentatively select sampling locations that bracket key tributaries and/or potential sources, and appear to be physically accessible.

2.2 Field Survey

Visually inspect the receiving water body (as access permits) to identify potential pollutant sources and evaluate potential sampling sites. Key tributaries and stormwater outfalls should be visually inspected. If dry weather flow is observed in a stormwater outfall, the flow will be traced upstream as far as possible (to the extent allowed by legal and physical access). Evidence of potential pollutant sources (discoloration, smell, etc.), if observed, will be evaluated following the Outfall Reconnaissance Inventory procedures specified in *Illicit Discharge Detection and Elimination*: *A Guidance Manual for Program Development and Technical Assessments* (Center for Watershed Protection and Robert Pitt, 2004).

2.3 Septic System Survey

If the existing data review suggests that septic systems are present in the basin, the County's sewer billing database and tax parcel database will be compared to identify "improved" parcels (i.e., parcels with > $25,000 of improvements) that are not served by the County's sanitary sewer system. A GIS map will be prepared to show the locations of these parcels. Those parcels with on-site sewage systems located near the receiving water body or its major tributaries will be included in the visual field survey described above.

3. SAMPLE COLLECTION PROCEDURES

The monitoring approach will involve periodic sampling at a set of fixed stations selected to bracket potential sources and/or key tributaries. If the core sampling results indicate that fecal pollution sources are affecting a given reach, supplemental sampling may be conducted in the tributaries or outfalls along the affected reach.

3.1 Fixed Station Samples

Surface water samples will be collected using a disposable bottle temporarily affixed to a pole or by hand dunking. All samples will be collected from just below the surface to the maximum extent practicable and care will be taken to avoid inclusion of floating debris in the samples. Grab samples will be collected directly into laboratory-provided, certified clean, bottles for storage and delivery to the analytical laboratory. Sample bottles and preservation requirements are provided in Section 5 below.

Each fecal coliform sample will be a composite of ten 100 milliliter (mL) sub-sample aliquots collected at approximately 2-minute intervals. A new 100-mL laboratory provided, certified clean, high density polyethylene bottle will be used to collect the 10 sub-samples that form the composite sample at each location. To avoid potential cross-contamination, a separate sub-sample collection bottle will be used for each sampling location. It is imperative that the sample collection jar be completely free of solvents or any other cleaning agents to avoid impacting surface water quality and sample integrity. The presence of solvents or cleaning agents may also kill bacteria, which are the subject of the fecal coliform and microbial source tracking analyses.

Each sample will be delivered to the IEH laboratory for fecal coliform analysis. The fecal coliform plates will then be analyzed using ribosomal RNA typing, as described in Attachment 1 to this appendix.

Samples will be collected from the highest stream velocity area within the reach of the sampling equipment. At stations with bridges, samples will be collected from the bridge using an extension pole. If flow allows, wading to collect the samples is the preferred sample collection method. If a bridge is not available and flow is too high for wading the samples may be taken from the shore. Regardless of the method, care will be taken to not disturb sediment or the stream bank at any time while approaching the stream or withdrawing the sample.

3.2 Supplemental Samples

The monitoring results will be reviewed following each round. If large increases in fecal coliform bacteria levels occur between the fixed stations, or if the MST data indicate unanticipated sources, supplementary samples will be collected from tributary creeks or stormwater outfalls that flow into the reaches in question. The locations of supplementary sampling will be determined on the basis of the results of the field survey and synoptic sampling. The supplementary surface water samples will be analyzed for the same parameters as the synoptic samples. Flow estimates of tributaries/drains sampled for source tracking will also be made. At least two rounds of sampling (one wet weather and one dry weather) should be conducted at each supplementary sampling location.

4. FIELD QUALITY CONTROL SAMPLING

One blind duplicate (field duplicate) surface water sample will be collected for each sampling event. These samples will be submitted to IEH for fecal coliform and MST analyses. A cross-reference table will be noted in the field book to track the location of the blind duplicates.

Blind duplicate samples will be assigned fictitious sample names so that the laboratory is unaware that the samples are duplicates. The fictitious sample names will be clearly cross-referenced in the field logbook along with field data for the primary sample. Details of the sample identification procedures are described in Section 5 below.

Duplicate water samples will be collected by filling two sets of sample bottles. Similar bottle types from the primary and duplicate sample will be filled in as close sequence as possible to ensure that similar water is being collected.

Disposable sample collection vessels will be used, mitigating the need for equipment rinsates.

5. SAMPLE HANDLING

Field personnel will be responsible for maintaining the integrity of samples from the time of collection to the time of delivery to the laboratory. Maintaining the temperature of samples at or below 4 degrees Celsius will aid in ensuring that analytical measurements are not biased and are representative. No field filtering of samples is required.

5.1 Sample Containers

The sampling team will obtain coolers, sample bottles, and bottle labels required for the water samples. Bottles for QA/QC samples and extra bottles to cover for breakage will also be obtained. Table F-1 lists the sample containers, analytical methods, preservation, and holding times.

Table F-1. Sample Containers, Analytical Methods, Preservation, and Holding Times

Parameter	Method	Container	Preservation	Holding Time
Fecal Coliform	SM9222D	1 L sterile glass	Cool to 4C	8 hours

5.2 Sample Preservation

Cooling immediately after sample collection is the only preservation required for the fecal coliform and MST analyses. Cooling should reduce the sample temperature to 4 degrees Celsius within 30 to 60-minutes of collection.

5.3 Sample Storage and Delivery

Samples must be contained and preserved as described in this section. Given the short holding time for fecal coliform, samples must be delivered to the laboratory at the end of each sampling day.

Samples must be stored at 4 degrees Celsius during on-site activities and transported to the analytical laboratory within eight hours of sample collection. Each cooler will be packed with bottles and padding material with enough room for ice. Ice will be placed in each cooler to maintain a sample temperature at or below 4 degrees Celsius. Care should be taken to ensure that the padding material does not act as an insulator to the ice.

5.4 Holding Times

Fecal coliform samples must be analyzed within eight hours of sample collection. The holding time starts when sample collection is complete and continues until the extraction, preparation, or analysis of the sample. For composite samples, the time of the initial sample aliquot is considered the “sample collection time” for determining sample holding time. If a sample is not analyzed within the designated holding times, the analytical results may be suspect. Thus, it is important that the laboratory meets all specified holding times and make every effort to prepare and analyze the samples immediately after they are received. Prompt analysis also allows the laboratory time to review the data and, if analytical problems are found, re-analyze the affected samples.

Holding times may affect the allowable sampling times. If the laboratory has not agreed to work evenings or weekends, given that each of the ten sampling events should require no more than 1 day, sampling events will be limited to Monday through Thursday to avoid weekend conflicts. The laboratory will be notified before the sampling begins so that it can prepare to analyze the samples immediately upon receipt.

5.5 Packaging

Labeled bottles will be stored in coolers, prior to sampling, in the exact way they will be shipped or delivered after sampling is complete. Each cooler will be packed with bottles and padding material and left with enough room for ice. This will aid the sampling team when packing the bottles after they are full. It will also save time, ensure that enough coolers are available for the sampling event, prevent over-packing of filled bottles, and reduce the chance of breakage. Coolers will be organized and labeled according to sample location. Chain of custody seals will be affixed if the coolers are left unattended.

At the end of each sampling day, the sampling crew will hand-deliver all of the samples to IEH.

6. SAMPLE IDENTIFICATION AND LABELING

Prior to sampling, labels will be affixed to bottles and filled in with as much information as possible. Typically, all information except the sampler signature, date, and time of collection can be printed on labels prior to sampling. The following is a list of all information that should be printed on the labels prior to submittal for analysis:

- Project Name and Project Number
- Sample Location
- Sample Identification
- Signature of Sampler
- Analytical Parameters for Bottle
- Date
- Time of Sample Collection

Each water sample will be assigned a sample identification (ID) based on location. Sample IDs will correspond with the sampling location identifiers. Samples from the same location collected on different dates will be differentiated by the collection date. Composite samples for MST will be appended with a "-C."

7. CHAIN-OF CUSTODY AND FIELD LOGBOOKS

7.1 Chain-of-Custody

Chain-of-custody procedures are essential when generating data that must be defensible. The possession of samples must be traceable from the time of collection through shipment, analysis, and final disposition. A sample is considered in a person's custody when it is in the physical possession or within the control of that person, secured in such a manner as to prevent sample tampering, or secured by a person in a restricted area.

Chain-of-custody procedures will begin when empty, certified-clean, sample bottles are obtained by the field crew. At that time, custody seals will be placed on the coolers that contain certified-clean sample bottles. When a cooler is opened, the person opening the ice chest will note in a field logbook the day, time and person breaking the seal. If the ice chests are opened prior to sampling (such as for confirming the bottle order), the ice chests shall be resealed with a signed and dated custody seal. The sample bottles shall be stored in secure, limited access areas. At no time prior to sampling will any bottle be opened; pre-opened bottles must be disqualified from sampling.

Sample custody will be documented on chain-of-custody forms supplied by the lab. All samples will remain in the samplers' possession or in a locked storage area until custody is relinquished. When transferring possession of the samples, the time and date of transfer and personnel will be noted on the chain-of-custody form and a copy will be retained by the sampling team leader. The remaining completed chain-of-custody forms will be securely taped to the inside lid of the shipping coolers in ziplock bags. The coolers will be secured with two, dated and signed custody seals, one on the front and one on the side, and strapping tape.

At the laboratory, custody is transferred to the laboratory sample custodian. The laboratory custodian will examine the condition of the custody seals on the shipping containers, verify the number of samples, check their identification and integrity, and sign and date the appropriate chain of custody forms. Any discrepancies will be noted on the laboratory's shipment acknowledgment form.

7.2 Field Logs

Documentation for all investigative samples will begin in the field at the time of sampling. Sufficient information will be recorded to allow the sampling events to be reconstructed without relying on the memory of field personnel. The documentation, in the form of field logbooks and sampling forms, will include the following information necessary for sample identification, sampling documentation, and custody records:

- Project and task number
- List of all personnel present
- Date and time of collection
- Sample number
- Sample location and identifying information
- Sample type
- Sampling method
- Number and volume of sample bottles
- Analyses required
- Field measurements and analyses (e.g., pH)

All field activities and observations will be documented in a field book.

8. FIELD EQUIPMENT CALIBRATION

All calibration procedures will follow the equipment manufacturers' specific instructions and requirements. Flow measurement equipment will be calibrated at the beginning of each day as prescribed by the manufacturer.

9. EQUIPMENT DECONTAMINATION

Equipment decontamination will not be required for the bacteria/MST samples because dedicated subsample bottles will be used at each station.

10. LABORATORY PROCEDURES

The composite sample will be delivered to the IEH laboratory for fecal coliform bacteria and Microbial Source Tracking (MST) analyses. Arrangements for sample transport will be determined as needed.

Prior to each sampling event the County sampling team leader will contact the laboratory regarding the number and types of samples that will be collected, the sample delivery date, and the sample containers that will be required. Any special circumstances including the collection of samples with short holding times or the potential of evening or weekend delivery of stormwater samples will be coordinated at this time.

When the the samples are delivered to the lab, a designated laboratory sample custodian will accept the samples and verify that the COC form matches the samples received. Samples will be logged in and assigned a unique laboratory sample identification number. Samples and sample aliquots, including extracts, will be tracked throughout the analysis process using laboratory routing forms. If any problems arise during analysis that delay reporting, the IEH project manager will notify the County project manager and the problem will be documented for use as necessary in the study report.

The laboratory will submit all analytical results in hard and electronic copy versions to the County within the standard turnaround time requested on the COC. The data package will contain a case narrative discussing any problems with the analyses, corrective actions taken, changes to the referenced methods, and an explanation of data qualifiers. The lab data package will also include QC results for all method blanks and check standards included in the sample batch, as well as results for analytical duplicates and matrix spikes.

The laboratory will provide the monitoring data in digital format in accordance with the County's Data Submittal Guide. The County will notify the laboratory prior to the start of the project that all data reports should provide or reference any information necessary to enter the data into the County's Environmental Information Management System (EIM).

Eight e. coli strains will be isolated from each sample, and the isolates will be frozen. After the first four rounds of sampling, the fecal data and other relevant information (e.g., flow, precipitation, groundwater elevation) will be reviewed, and a subset of the isolates will be selected for ribotyping to identify the specific sources (human, dog, cat, goose, etc.). Theses isolates will be selected based on the fecal coliform counts in the associated water samples. For samples with less than 200 cfu/100mL, ribotyping will be done on two E. coli strains per sample. For samples with >200 to <1,000 cfu 100/mL, ribotyping will be done on four E. coli strains per sample. For samples with >1,000 cfu 100/mL, ribotyping will be done on eight E. coli strains per sample (or as many as are available in the sample, if less than eight).

In addition to fecal coliform densities, other factors, such as flow rate or unusual land use activity, may be considered in the selection of isolates to be analyzed, to ensure that each study encompasses a broad range of conditions.

This sampling approach will provide detailed source information (to the species level) for hundreds of the E. coli strains in each study. The frequency of each source will be calculated on the basis of the results. In addition, the County will be able to compare the source data associated with the low (<200), medium (200-1,000) and high (>1,000) fecal coliform samples, to see if there are any apparent differences.